DOCUMENT RESUME

ED 125 861 SE 019 544

AUTHOR Murtha, D. Michael; Nadler, Gerald
TITLE A Comparison of Problem-Solving Alternatives Used by Environmental Designers. Final Report.
INSTITUTION Wisconsin Univ., Madison.
SPONS AGENCY National Center for Educational Research and Development (DHEW/OE), Washington, D.C. Regional Research Program.
BUREAU NO BR-1-E-159
PUB DATE Jun 73
GRANT OEG-5-72-0012(509)
NOTE 320p.

EDRS PRICE MF-$0.83 HC-$16.73 Plus Postage.
DESCRIPTORS *Architecture; Design; *Educational Research; *Environment; Graduate Students; *Higher Education; Instruction; Physical Environment; *Problem Solving
IDENTIFIERS *Environmental Design; Research Reports

ABSTRACT

This study compared the effectiveness of three design strategies using nine architecture graduate students to solve three typical room design problems. Open-ended (5 step), traditional (10 step), and systematic (15 step) strategies were developed based on a national survey of design methodologists. Each strategy was applied by three subjects working independently in three 8-hour test sessions to provide designs for a faculty office, campus snack bar, and departmental conference room. Analysis of variance indicated significant differences existed for problems and for subjects within strategy groups. Some significant strategy effects were found over all three problems (8 measures), on individual problems (16 measures), and in strategy-problem interactions (24 measures). The 5-step strategy required a large amount of time, using large quantities of information minimally applied; the 10-step strategy concentrated on a detailed problem development with a low use of conceptual information; and the 15-step strategy operated more efficiently overall, producing nonsignificantly, but apparently, better solutions. Interaction results suggested that the 5-step strategy reacted similarly to all three problems; the 10-step strategy became more efficient over the three sessions and the 15-step strategy demonstrated sensitivity to problem differences. Implications for design methods and research are discussed. (Author/BT)

Final Report

Project No. 0-E-159
Grant No. OEG-5-72-0012(509)

D. Michael Murtha
Gerald Nadler
University of Wisconsin
1513 University Avenue
Madison, Wisconsin 53706

A COMPARISON OF PROBLEM-SOLVING ALTERNATIVES USED BY ENVIRONMENTAL DESIGNERS

June 1973

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Office of Education

National Center for Educational Research and Development
(Regional Research Program)

Final Report

Project No. 1-E-159
Grant No. OEG-5-72-0012(509)

A COMPARISON OF PROBLEM-SOLVING APPROACHES USED BY ENVIRONMENTAL DESIGNERS

D. Michael Murtha
Gerald Nadler

University of Wisconsin

Madison, Wisconsin

June 30, 1973

This research reported herein was performed pursuant to a grant with the Office of Education, U.S. Department of Health, Education and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions do not, therefore, necessarily represent official Office of Education position or policy.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
National Center for Educational Research and Development
(Regional Research Program)

Preface

This research was supported in part by a grant from the U.S. Department of Health, Education, and Welfare, Office of Education, Regional Research Program.

Grateful acknowledgement is given for the contributions made: by the faculty advisory committee, Gordon Robinson, Department of Industrial Engineering; Charles Bridgman, Department of Psychology; Leo Jakobson, Department of Urban and Regional Planning; Ralph London, Department of Computer Science, Ronald Wyllys, Department of Library Science; by the technical consultants on apparatus design, Edward Falk and Howard Hagens, Instrumentation Systems Center; Walter Meives, Department of Photography; Theodore Tibbitts, Department of Horticulture; by the hosts for the experiment, the School of Architecture, University of Wisconsin, Milwaukee, especially Professor Leonard Kitts; by the professional solution evaluators, Gordon Orr, Campus Architect, Byron Bloomfield, Department of Environmental Design; Thomas Nisbet, John J. Flad and Associates.

Special appreciation is given for the project assistance of Susan Harrison, Robert Ocegueda, and Diane Kurtz; and the staff assistance of Mary Dokken, Department of Industrial Engineering and Joanne Zimmerman, Engineering Experiment Station.

ABSTRACT

An experiment comparing the effectiveness of three design strategies used nine architecture graduate students solving three typical room design problems. Open-ended (5-step), traditional (10-step), and systematic (15-step) strategies were developed based on a national survey of design methodologists. Each strategy was applied by three subjects working independently in three 8-hour test sessions to provide designs for a faculty office, campus snack bar, and departmental conference room.

The design process was recorded every 30 seconds when a camera photographed the work area on which subjects displayed and manipulated cards taken from an information bank. The bank contained over 800 data items on requirements, design criteria, and solution alternatives for each problem. Thirty-five process measures were generated including: time for solution, number and type of cards used; number and type of relationships formed with the cards. Twenty-five solution measures covered the differences in design configuration and quality, including ratings of judges.

Analysis of variance indicated significant differences existed for problems and for subjects within strategy groups. Some significant strategy effects were found over all three problems (8 measures), on individual problems (16 measures), and in strategy-problem interactions (24 measures). The 5-step strategy required a large amount of time, using large quantities of information minimally applied; the 10-step strategy concentrated on a detailed problem development with a low use of conceptual information; and the 15-step strategy operated more efficiently overall, producing nonsignificantly, but apparently, better solutions. Interaction results suggested that the 5-step strategy reacted similarly to all three problems; the 10-step strategy became more efficient over the three sessions; and the 15-step strategy demonstrated sensitivity to problem differences. Implications for design methods research are discussed.

TABLE OF CONTENTS

TABLES

FIGURES

CHAPTER I - INSPIRATION: The Need For Design Methods Research

Introduction:

Design methods, the working techniques and procedures used by professional designers in fields such as architecture and engineering, have been regarded with interest in recent years as one avenue through which the efficiency and effectiveness of design activity could be improved. This interest has been prompted by a growing awareness that past, traditional and intuitive methods are proving inadequate to deal with current problems of social and technical complexity. However, the development of effective new methods has been frustrated by the lack of appropriate controlled research in the areas of complex problem-solving and design methods. This study represents an attempt to provide a more rigorous examination of selected design methods and their interaction with the design process. Specifically, the emphasis is on methods used in Environmental Design, a field representative of a broad range of design-oriented disciplines.

ENVIRONMENTAL DESIGN

Environmental design is an emerging discipline which encompasses Urban Design, Architecture, Interior and Product Design. This discipline links the previous loose community of designers and design activities within an overall framework which permits approaching and solving problems at all levels of human environment (Maldonaldo, 1966; Malone, 1960; Musgrove, 1966; Van der Ryn, 1966). As such, by definition and inclina-

tion, it is involved in the interdisciplinary concern for design methods. This concern has been described by Simon (1969) as the "science of design," represented by fields such as engineering, architecture, business, law, and medicine. Simon identifies the common aspects of these fields under a definition of design as "devising courses of action changing existing situations into preferred ones". Environmental design can therefore serve as a typical example, with current difficulties and potential method utilization similar to other disciplines.

A. Environmental Design Responsibility

The area of responsibility for environmental design is "inventing physical things which display new order, organization, and form in response to human function" (Alexander, 1969). Within this definition, "physical things" can involve any aspect of the built environment "from a city to a teaspoon" (Maldonaldo, 1966). Particular aspects of human function have been defined as "freedom of choice, physical and mental health, and a richness and depth of human experience" (Geddes and Spring, 1967). The critical nature of the field is apparent when these definitions are applied to specific environments associated with housing, educational and health facilities, work places, transportation, etc.

B. Environmental Design Difficulties

It should be apparent to most observers of modern society that environmental designers have not been adequately

solving problems in their area of responsibility. Some designers have noted this general ineffectiveness in terms of "nightmare of the cities" (Wachsman in Banham, 1965); "discomforts heaped on us by ill-design" (Van der Ryn, 1966); "mismanagement through anti-design" (Maldonaldo, 1965). These shortcomings have been related to the "quantity", "complexity" and "difficulty" of current problems associated with changing social patterns and culture (Alexander, 1964). Other causes have been identified in terms of new production capabilities which can reproduce "almost any desired shape in almost any material" (Pye, 1964). In particular, it has been observed that changing conditions have forced the designer to assume a decision-making burden far more complicated than in the past, where options were severely limited, and designs were frequently based on centuries of adaptation and development (Alexander, 1964; Archer, 1960).

C. Environmental Design Information

The difficulties experienced by environmental designers in decision-making have been traced in part to the increased load on information handling capabilities within the design process. In general, the information load is an inevitable result of technological innovation which produces a doubling of available knowledge every 10-15 years (Price, 1961). For environmental designers the situation has been described as a "growing body of knowledge and specialist experience" with problem statements becoming more comprehensive in scope and

more complicated in nature (Alexander, 1961; Cheetham, 1964). In addition, the information available for environmental designers has been referred to as "hard to handle", "diffuse", and "disorganized" (Alexander, 1964). The situation is described by one author as "it is difficult to find even modest, accurate, and systematized information on any aspect of architectural practice" (Passonneau, 1965). Without proper methods for coping with this information burden, the designers' information processing capabilities are often overloaded (Alexander, 1964).

D. Environmental Design Methods

The present recognition given design methods in the field is particularly significant in light of the past reliance on traditional approaches, characterized by an emphasis on intuition and practical experience (Cheetham, 1964; L. Jay, 1963; Maldonaldo, 1965). The awkwardness of these methods is suggested by Archer (1970):

> Traditionally, the designer has worked intuitively for the most part, studying his brief, scanning the evidence, ruminating upon implications, and sketching ideas without exercising much conscious control over the activity of design decision-making itself.

The concern for alternative, more effective methods has been expressed in terms of the need to "emerge from cloudy pragmatism" (Malone, 1960); using "a methodical modus operandi" (Corkill, 1968); a more methodical and logical way of working" (Thornley, 1963); and establishing "sound heuristics for de-

sign problem-solving" (Kitts, 1965). In particular, an emphasis has been placed on "systematic" ways of working, which could control problem information and lead to more effective results (Archer, 1965; Blake, 1962; Handler, 1964; Jones, 1963).

DESIGN METHODS

Design methods, despite their importance, have been interpreted in a number of different ways, without any definitive statement of the concept. In general terms, "methods" usually suggest a mental procedure or set of procedures, which provide an approach or framework to guide the designer's thoughts or actions (Eder, 1966; Gutman, 1966; McCrory, 1966). Synonyms for design methods include: "strategy", "subroutine", "tricks of the trade", "rules of the game" (Amarel, 1966; Eder, 1966; Newell et al., 1959; Thomas, 1965). Qualifications on the use of methods suggest that they are not to be used as a recipe, followed step-by-step, but rather are to be used flexibly, adapted to a specific situation, as an aid, not a replacement for intuition (Archer, 1970; Gutman, 1966; Krampen, 1965).

A. Utility of Design Methods

The utility of appropriately developed methods has been described in terms of the potential for aiding the designer, particularly in the area of information processing. In overall terms, it is suggested that a specific approach can influence the level, type, and sequence of information usage within the

design process (Mitroff, 1968; Ranstrom and Rhenman, 1965). For one method the advantages were described as:

> aids the consciousness to focus on objectives, analyze problems, and select, reject, and organize data in those patterns likely to produce subconscious closure and interpretation (C. Gregory, 1967).

In the area of visualization, specific reference is made to "expressing the brief in terms that make possible a systematic method of designing (M. Jay, 1967), and "a way of presenting design problems that does make them easier to solve" (Alexander, 1964).

In processing information, methods may assist in directing the search for a solution and evaluating alternatives with a minimum of error, redesign, and delay (Amarel, 1966; Jones, 1963; Miller et al., 1967). Simon (1969) provides one interpretation of method advantages as:

> management of the resources of the designer so that his efforts will not be dissipated unnecessarily in following lines of inquiry that prove fruitless.

The potential outcome of these aids has been given in terms of "the evolutionary development of successfully improved solutions" (Roe et al., 1967), and "more imaginative and advanced designs" (Jones, 1963).

B. Availability of Design Methods

Alternative design methods have been developed in recent years by practitioners in environmental design and related fields in an effort to realize the potential advantages of appropriate methods. Major methods developments have been

attempted by Archer (1970); Asimow (1964); Nadler (1970); C. Gregory (1967); Roe et al. (1967). Symposia and collections of articles, on different techniques and methods, have been edited by Jones and Thornley (1963); Zwicky and Wilson (1967); S. Gregory (1966); and Moore (1970). Comparisons of different methods have been made by Alger and Hay (1964); Whitfield (1968); Guilford (1967); and Jones (1966). Engineering design methods have been described by Buhl (1960); Dixon (1966); Pare et al. (1963); Roylance (1966); Wilson (1965). Specific design techniques have been developed by Gordon (1968); Alexander (1964); Alexander et al. (1968); Goode and Machol (1967); Starr (1963). Computer-aided design has been discussed by Campion (1968); Fetter (1965); Siders (1966).

C. Developing Design Methods

The majority of the available methods, however, are empirically based, the result of individual experience. Such methods have been described as "applying their favorite principles to the design problem" (Gutman, 1966), and making explicit "the practices that discerning people seem to be adopting" (Archer, 1970). Even when these methods have been adopted or adapted from other disciplines such as philosophy, social science, economics, computer science, management science, and engineering (Barnett, 1966; S. Gregory, 1966; M. Jay, 1967), these methods have themselves often been empirically based, and their application has usually not been systematically determined (Studer and Stea, 1966). There appears to

have been little, if any, attempt to develop design methods in a controlled scientific manner, permitting a rigorous analysis and evaluation of their effects. This aspect has been summed up by:

> Definitions of "better" methodologies are meaningless unless we are told in what respects a method is better than other methods (Kaiser, 1952).

D. Design Methods Research

It should be apparent that the only way to develop design methods beyond their present informal level is to follow the course taken by other disciplines in moving from an empirical to a theoretical knowledge base. This concept has been described in terms of investigating the nature of the design process and determining the ways in which methods could be appropriately applied in each phase of design activity (S. Gregory, 1966; Kitts, 1965). The scope of such an investigation has been suggested by De Groot (1966):

> From experimental evidence and analysis, it must be possible to develop an ordered classification of human mental operations to cover every method, trick, heuristic, transformation that may be instrumental in productive thinking.

The type and level of research which is needed is quite extensive, but it should be apparent that in a quest for valid "systematic" methods, that equally rigorous means of investigation should be employed. The significance of such research activity has been described in the strongest terms by Simon (1969):

The professional schools will reassume their professional responsibilities just to the degree that they can discover a science of design, a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process.*

CHAPTER II - INVESTIGATION: Approaches To Design Methods Research

Introduction:

Design methods research, on almost any aspect of design process or methods, must be based on the study of design problem-solving, the act of designing. Previous experience by cognitive psychologists has indicated great difficulty in studying human problem-solving behavior. Some techniques have been developed, but these involve a number of short-comings. While there have been some studies in design-related fields, these have not dealt with the details of complex problem-solving nor have they attempted to use design methods as an independent variable. The purpose of this study is to demonstrate a new approach to design methods investigation. This approach is based on systematically comparing alternative design methods, using a research technique adapted to the identification of the impact of methods on the design process.

DESIGN METHODS RESEARCH

The observation of the workings of the design process poses particular difficulties since by tradition and practice most design activity consists of subconscious or covert behavior, with most reasoning and critical decision-making remaining within the mind (Eder, 1966; Thornley, 1963). In most cases the only evidence available is the solution presentation and a limited display of notes, sketches, or calculations (Eder, 1966). While it may be possible to make some general

observations from this evidence, the critical details remain out of reach (Bloom, 1950; John and Miller, 1957). The basic difficulty has been described as the "problem how to observe and measure the process" and reference is made to the "methodological difficulty in externalizing the process in an operational way" (John and Miller, 1957).

A. Research Techniques

Some techniques have been developed in attempting to make the problem-solving processes observable. One author has described these techniques as means of "bringing the covert processes into the open" (Forehand, 1966). The use of the technique has been referred to as "exploring the process itself - investigating the subject's thoughts, feelings, and reactions - as he attacks the problem (Bloom and Brodel, 1950).

Retrospection represents one technique which has been used either alone or in combination with other methods. This technique usually consists of an interview or questionnaire after the problem-solving session, in an attempt to recall and reconstruct the processes which were used (Clarkson and Pounds, 1963; John and Miller, 1957; Mitroff, 1968). Due to difficulties with memory and reconstruction, this technique is not too reliable, but it can be useful for identifying major occurrances and subjective observations.

Introspection is an alternative technique based on eliciting information from the subject while he is in the process of

solving a problem (John and Miller, 1957). The record generated using this technique is usually referred to as a "protocal" (Newell and Simon, 1961), which is intended to represent a picture of the cognitive process used by the problem-solver. Introspection is usually preferred over retrospection as providing a more literal, accurate picture of the subject's behavior (Clarkson and Pounds, 1963).

Thinking Aloud is a particular technique for generating introspective protocols, based on subject verbalizations which are recorded on magnetic tape as he attempts to solve or think-through a given problem (Clarkson and Pounds, 1963). A specific description of the application of this technique is given by Miller et al. (1969) as:

> Thinking aloud requires merely that the person talk while he is working, that he should comment on what he is doing, what he is looking for, what his intentions are, what objects or relationships catch his attention, etc.

These authors have cited the popularity of the thinking aloud technique "used by Binet, Duncker, Claperede, and many others" and indicate its advantages, "when the method is used intelligently and conscientiously, it can provide a tremendous amount of information about the detailed process of thought". However, this method has some drawbacks which will be shown later in the discussion.

B. Problem-Solving Research

A large number of studies have been completed, using the above techniques. However, most of the work has had minor

impact on design methods research since the emphasis has been on basic "problem-solving", using relatively simple, highly constrained test problems. The early work is characterized by Maier (1931) and Duncker (1945) who studied subjects solving physical and mathematical logic problems. Their emphasis was on demonstrating the formation of specific conceptual relationships as the keys to solving problems. This approach and that of related studies was based on concepts related to Gestalt psychology, and similar work investigated mechanisms related to "deductive" and "inductive" reasoning, and "concept formation" (Wason and Johnson-Laird, 1968).

An information processing approach to problem-solving was taken by several investigators, typified by Newell, Simon, Paige, and others (1958, 1959, 1961, 1966). This research relied heavily on thinking aloud protocols generated by subjects involved in somewhat more complex tasks such as symbolic logic and algebra word problems. The outcome was a comprehensive analysis of these problem-solving activities with the development of information processing models based on "objects" or problem states, transformed by "operators", which were "applied to certain objects to produce different objects". For the relatively simple, essentially mechanical, problems being studied it was possible to represent human problem-solving behavior using computer programs such as the LOGIC Theorist, GPS (General Problem Solver) and STUDENT.

C. Design Research

Researchers in engineering and environmental design have attempted to investigate aspects of complex problem-solving. However, these studies have tended to be more general and open-ended than the controlled studies of basic problem-solving. Typical studies were performed by Dixon (1964), Ranstrom and Thenman (1965), Frischmuth and Allen (1969), consisting of observations of work done by practicing engineers on their real-world problems, using notes, tapes, and interviews. The results of these studies were general models of the design process expressed as "flowcharts" (Frischmuth and Allen); and "need", "engineering", and "product" dimensions or development stages (Ranstrom and Rhenman).

Similar studies were performed by Mitroff (1969) and Reitman (1970) using more detailed thinking aloud protocols to investigate specific aspects such as designer's attitudes and other subjective factors; and interactions with "open-ended" or "ill-defined" information, respectively. The results of these investigations suggested that even in relatively constrained problem-solving situations there was considerable dependence on individual interpretations.

Particular controlled design studies were conducted by Meister and Farr (1966, 1967) using subject groups of 10-20 engineers working on pre-specified instrument panel or console design problems. The experimenters provided design specifica-

tions and background information, including data on human factors requirements, and employed observation of subjects at work, subject comments while working, and in-depth retrospective interviews. These techniques were used to determine the extent of human factors information utilization. The results indicated that the subject-designers generally used a much more superficial problem analysis than had been anticipated by the experimenters, and that subjects usually ignored human factors data presented in the typical handbook form.

Research studies in environmental design have been less numerous, but follow the patterns associated with other disciplines. A typical simplified experiment was used by Krampen (1965), with classroom students working on a graphic layout problem with highly constrained problem specifications. Thinking aloud protocols were generated and used to demonstrate to students basic steps in problem-solving such as "definition," "solution", and "verification".

A similar experiment was used by Eastman (1969) with a large number of subjects solving a "space planning" problem, using a highly constrained format with specific rules for location of elements. Relatively detailed thinking aloud protocols were used in an information processing analysis, identifying "operators" or transformations and "tables of connections" which indicated different applications of the design rules. The work was also used to demonstrate "search

strategies" identified by Newell and others as "generate and test" (trial and error); "means-end analysis" (sequentially applied constraints); and "planning" (solving problems by subsystems).

Another study by Eastman (1970) used a more open-ended problem-solving task, the <u>design of a bathroom layout</u>, with minimal requirements and an emphasis on individual insight and past experience. Analysis of problem-solving was based on thinking aloud protocols and graphic sketches. Results indicated a correlation between the form of the requirements and their representation by subjects, and cited the superiority of dependence on information stored in the memory over requirements given with the problem.

D. Research Implications

The major observation from the review of related studies is that there has been little or no research related specifically to design methods. Where research has been related to design, the emphasis has been on studying how design practitioners use traditional, intuitive methods rather than considering the effect of alternative improved methods. The work does suggest the possibility of observing and analyzing design behavior, but it is necessary to go beyond the consideration of limited problems and specific mechanisms to consider design problem-solving in greater detail. In particular, it is necessary to begin filling-in the specific behaviors associated

with the major stages or overall approaches used by designers, and to begin describing how different types of information interact throughout the design process. To accomplish this, design methods research must not only test and compare alternative methods, but must also develop tools for studying and analyzing complex problem-solving behavior with a rigor which will provide a sound theoretical basis for understanding the mechanisms and interactions which are involved.

In another aspect of the related research, the "thinking aloud" technique does not seem to be effectively applicable to design methods research. This technique has been criticized in terms of: a) its potentially inhibiting effect on problem-solvers; b) the difficulties with confusing terminology, ommissions, and inaccurracy; and c) the effort in transcribing lengthy problem-solving sessions (Bloom and Brodel, 1950; Miller et al., 1969). An alternative technique is required which could offset these disadvantages and add greater control in terms of 1) accuracy in determining sequence and chronology of events; 2) standarized coding of information and responses; 3) identification of relationships between elements in the process (Bloom and Brodel, 1950; De Groot, 1966; Forehand, 1966).

PRESENT RESEARCH APPROACH

The purpose of this study was to make a pilot attempt at design methods research, using design methods as the major

research variable, in an experimental setting designed to generate specific behavioral data about the effect of methods on the designer-subject's problem-solving process. This attempt was based on implications of the related research and the nature of design methods as previously described.

A. Comparing Design Strategies

Design strategies were selected as methods whose effectiveness could be usefully compared in terms of their prominent role in the design methods literature, and their impact throughout the problem-solving process. Strategies have been defined as "plan of attack, methodology, or approach", which is characterized by:

> An iterative series of steps defining the direction or pattern of action to be followed by an individual or group in achieving a purposeful activity (C. Gregory, 1967).

As indicated earlier, strategies were identified by extrapolation in several engineering design studies, and in some of Eastman's work. Theoretical discussions have occurred in the work of Nadler (1970), Jones (1966), Archer (1970), and C. Gregory (1967), among others.

Strategy differences have been described by C. Gregory (1967) as a result of a survey of strategies which demonstrated variations in terms of: a) specific steps mentioned by some authors and omitted by others; b) combinations of steps under more general terms; c) transpositions in the order or sequence

of steps; d) differences in the total number of steps. These differences may lead to different strategy impacts as described with the specific experimental hypothesis on pages 38-39.

An important aspect of a comparative study of design strategies is the opportunity to refute current misconceptions that either strategies have no effect on the design process or all strategies are essentially the same. This latter attitude is suggested by Eder (1966) referring to a given strategy example, "all methodologies so far proposed fit into the design sequence outlined above".

B. Complex Design Task

The observation of a subject working on a relatively complex design problem-solving task was determined as the most appropriate setting to compare the effectiveness of design strategies. This determination was based on the need to obtain more controlled data in general on complex problem-solving, and need for sufficient scope to determine strategy effects on a range of behaviors within the design process. For this research such a task would involve the design of an environmental setting such as a room or similar space accommodating a range of activities related to a specific purpose or function. This task would be considerably more complex than a simple logic or layout problem, and would have a somewhat broader scope than Meister and Farr's console problem or Eastman's bathroom. The need for research at this level has

been acknowledge by Green (1966) as an "interest in complex or as they say 'rich' experimental settings so that the complex structure of man's behavior can be displayed".

C. Observation Technique

An experimental technique which generates data on the subject's use of "information" within the design process was identified as most appropriate to design methods research. This was based on the understanding developed earlier that information processing is considered to be an important element in design problem-solving and a major area affected by design methods. Such a technique would develop an information processing protocol, a record of the individual information items used in problem-solving, generated as the information was actually used, and including manipulations and relationships associated with specific information items.

The key to the technique would be an information bank, a collection of information in various categories covering all aspects of the problem-solving task. A separate information bank could be pre-specified by the experimenter for each design problem, and subdivided into separate items. The items could then be printed on individual cards and physically selected and manipulated by the subject as an analog to personal notes or mental manipulations. This technique was intended to provide a relatively natural working medium, simplifying the processes of information search, retrieval, and manipulation, and providing for a direct recording of design behavior in

terms of information patterns. This would be in contrast to the indirect thinking aloud approach which concentrated on subject perceptions. By making the process literally observable through the use of sets of information cards, it should be possible to obtain a standardized, highly accurate, highly reliable record, with a clear reading of sequence, duration, and relationships.

While this technique was distinctly different from the approaches used in most of the related research, it was suggested by controlled information formats used in many of the problem-solving studies. Although the use of information items as a design medium is somewhat unusual, this approach has been suggested by several design practitioners, who have recommended recording and manipulating information using index cards or slips of paper (Burnette, 1967; C. Gregory, 1967; Jones, 1966). In a theoretical sense, information protocols are consistent with the view of the design process described by several authors as an information image being continually developed and refined in progressing from an initial problem definition to a final solution (Burnette, 1967; S. Gregory, 1966; Forehand, 1966; Krampen, 1965; Miller et al., 1969).

E. Experimental Design

A 3x3 factorial design, comparing three design strategies, used to solve three problems, with three subjects using each strategy, was determined as an appropriate scale for this pilot research, providing some variety and comparison of differences.

within the resources available to the experimenter. This offered particular advantages since by comparing three strategies it was not necessary to use a separate control group (using no strategy). By comparing strategy effects over three problems it would be possible to check on the generality and consistency of the strategies, with some control over differences in subject background and experience which might have favored any given problem. It was determined that each subject should use the same strategy for all three problems, because of the likelihood of confusion and contamination if subjects were asked to change strategies between problems. This design also permits a statistical analysis of variance to determine effects of strategies, problems, subjects within strategies, and strategy-problem interaction.

	STRATEGIES								
	5-Step			10-Step			15-Step		
Subjects	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Problems I									
II									
III									

Figure 2-1 Experimental Design

E. Subjects

Advanced environmental design students were initially identified as a general subject type appropriate to this research. This was based on the assumed need for subjects able to solve complex design problems in a reasonably brief

period of time, and the relatively large time committment required for orientation and for three problem-solving sessions. Students also seemed desirable in terms of their availability on campus, their generally high level of interest and motivation, and their relative flexibility in working habits as compared with professionals.

CHAPTER III - INSTALLATION: Development of Experimental Materials

Introduction:

Specific experimental materials, problem types, test strategies, information banks, and apparatus were developed using controlled systematic procedures. These procedures were used to provide the best possible tools for this research, with a comprehensive description of the development process for use by other design methods researchers.

TEST PROBLEMS

Problem-solving tasks were selected using criteria developed and applied to problem alternatives through a series of questionnaires submitted to a committee of consultants (the experimenter's faculty advisory committee).

A. Establishing a Problem Area

The range of problem alternatives was limited to facilitate criteria and problem generation. Environments associated with college classroom buildings were selected in order that their familiarity to subjects could reduce the time required for problem definition and orientation. Such environments also: a) are familiar to the experimenter; b) offer a variety of settings; and c) have a likelihood of existing information and expertise available on the campus.

B. Advisory Committee

The advisory committee was involved because of the breadth

of expertise represented by the following academic departments and subdisciplines:

1. Industrial Engineering (design methods and systems)
2. Industrial Engineering (human factors, ergonomics)
3. Psychology (engineering and perceptual psychology)
4. Computer Science (information systems)
5. Urban Planning (architecture and environmental design)

These fields include aspects relevant to environmental design and the consideration of research tasks and experimental designs. Faculty members should also have a sensitivity to facilities for higher education.

C. Delphi Procedure

An adaptation of the "delphi procedure" (Quade, 1968; Rescher, 1969) used a series of questionnaires, permitting the committee members to note the responses of their colleagues as an additional factor in making subsequent decisions. This allowed the committee to participate in a simplified dialogue and search for a consensus without physically meeting. Two questionnaires were used for criteria selection and a final questionnaire was used for applying the criteria to problem alternatives.

D. Criteria Review Questionnaire

The first questionnaire presented the committee with a tentative list of criteria for their review and comment. Criteria were generated by the experimenter based on the needs

of the experiment and the characteristics of problems which might be evaluated (Appendix A-1). The specific criteria titles were as follows:

1. Comparable to other Problems
2. Environmental in Character
3. Availability of Background Information
4. Motivates Subjects
5. Understandable to Subjects
6. Permits wide range of Solution Possibilities
7. Reasonable to Expect Solution within Time Constraints

Criteria presentation included: a) a brief review of the delphi procedure; b) an explanation of the initial choice of problem area; and c) a simplified description of the role of test problems in the experiment. A response sheet provided for comments on the individual criteria and on criteria that might have been omitted. The results affirmed the proposed criteria and suggested minor modifications which were included in a revised criteria list for the second questionnaire (Appendix A-2).

E. Criteria Rating Questionnaire

On the second questionnaire the committee members were asked to compare the different criteria and estimate the relative differences in importance. The revised criteria were presented to the members with an expanded set of definitions to aid in understanding (Appendix A-2). The response sheet required an indication of differences on a linear scale

as an aid in visualization and a means of insuring comparability of results. The results of the questionnaire are presented in Table 3-1, showing the ratings for each criterion numerically translated from their linear positions. The ratings were frequently inconsistent, and in several instances members assigned very different ratings to the same criterion (A, B, D, G). Given the mixed results, it was not possible to confirm or reject any specific criterion, or to assign any meaningful weighting.

Table 3-1 Responses on Criteria Rating Questionnaire (numerical equivalents of linear positions, 10 = high)

CRITERIA	RESPONDENTS				AVER.
	A	B	C	D	
A. Comparable With Other Problems	5.7		0.6	3.6	2.5
B. Environmental Design Task	9.9	10.0	2.4	4.5	6.5
C. Availability of Background Information	9.0	10.0	6.9	9.9	9.0
D. Motivates Subjects	1.8		8.4	8.7	4.8
E. Time Constraints	8.4		9.6	7.2	6.3
F. Comparable Within Problem Area	6.6	10.0	9.0	7.8	8.4
G. Uniqueness of Problem	0.6		5.4	9.3	3.8

F. Problem Selection Questionnaire

In the third questionnaire, a selected set of criteria (Appendix A-3) were applied to a number of problem alternatives developed by the experimenter to represent environmental systems with a range of components or elements to be provided. Problems were eliminated from the larger set of alternatives in the educational area if they were too complex in terms of variety of spaces, activities, or unique technology. The typical classroom was also excluded as being too simple under present interpretations and too complex if thoroughly designed for new teaching techniques. The final set of alternatives (Appendix A-4) was subdivided into three different categories to maintain the distinction between problems, as shown below:

Group I	Group II	Group III
A. Faculty Office	E. Dept. Conference Room	I. Campus Snack Bar
B. Administrative Office	F. Lab Discussion Room	J. Dorm. Floor Lounge
C. Research Office	G. Teaching Discussion Room	K. Departmental Lounge
D. Teaching Asst. Office	H. Audio-Visual Room	L. Coffee Shop

A paragraph description identified the alternatives, without descriptive titles in order to minimize bias in terminology. One response sheet was provided for each of five criteria, with cues representing high, middle, and low values (Appendix A-3). Cue statements were included at relative intervals

along a linear scale. The response format required the members to rate the four alternatives in each group, with the understanding that the best problem in each group would be used in the experiment.

The results of the third questionnaire are shown in Table 3-2, again using numerical equivalents to represent linear positions. The results were once more varied and contradictory, and in some cases committee members completed only a portion of the questionnaire. However, the results identified several problems as overall high scorers. The scores were used in a further screening of the problems by inspection. The final selections were made as follows: (I) the faculty office was relatively more clear-cut than the TA office with a likelihood of considerably more background discussion in the literature; (II) the departmental conference room was more appropriate than the two classroom-types which seemed too open-ended, and the audio-visual laboratory which seemed to be technically difficult; (III) the campus snack bar was less technical than the coffee shop, the departmental lounge was too similar to the conference room, and the dormitory lounge was too remote from the classroom building. The selections seem to provide a representative set of problems within the bounds of the criteria. In retrospect, despite the inconsistencies in the questionnaire technique, it does seem that the more explicit examination and decision-making resulted in a more rigorous selection of problems than would have been likely using less formal methods.

Table 3-2 Responses on Problem Selection Questionnaire. (numerical equivalents of linear positions, 10 = high)

CRITERIA		PROBLEM ALTERNATIVES (a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
Comparable To Other Problems	A	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
	B	8.5	[illegible]	[illegible]	8.5	[illegible]	4.5	8.5	6.5	[illegible]	8.5	8.5	1.5
	C	1.5	3.5	5.5	8.0	4.0	4.5	5.5	3.5	3.5	6.5	5.0	2.0
	T	14.5	16.5	18.5	21.0	17.0	13.5	18.5	14.5	16.5	19.5	18.0	8.0
Motivates Subjects	A	1.5	[illegible]	0.5	2.0	5.0	2.0	7.0	9.0	5.0	7.0	6.0	4.5
	B	2.0	4.0	8.0	9.0	9.0	9.0	9.0	9.0	9.0	7.0	9.0	4.5
	C	2.0	2.0	4.0	6.0	7.0	5.0	6.5	8.5	3.0	7.5	6.0	5.0
	D	6.0	4.0	10.0	8.0	9.0	6.0	4.0	9.0	5.0	10.0	8.0	5.0
	T	11.5	18.0	22.5	25.0	30.0	22.0	26.5	35.5	22.0	31.5	29.0	19.0
Time For Solution	A	9.0	9.0	9.0	9.0	9.0	4.5	9.0	4.5	4.5	9.0	9.0	4.5
	B	10.0	9.0	9.0	9.0	9.0	6.5	9.0	8.0	8.0	8.0	8.0	6.5
	C	8.0	3.5	5.5	6.0	7.5	5.0	8.0	4.0	6.0	3.0	7.5	4.5
	D	8.0	8.0	4.0	8.0	8.0	8.0	8.0	4.0	10.0	8.0	5.0	5.0
		35.0	29.5	27.5	32.0	33.5	24.0	34.0	20.5	28.5	28.0	29.5	20.5
Available Information	A	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	9.5	4.0	4.0	9.5
	C	8.5	7.0	7.0	6.0	7.0	5.5	5.0	7.0	5.5	6.5	5.5	5.0
	T	12.5	11.0	11.0	10.0	11.0	9.5	9.0	11.0	15.0	10.5	9.5	14.5
Comparable Within Problems	A	9.0	9.0	9.0	9.0	9.0	4.5	9.0	4.5	4.5	4.5	4.5	4.5
	B	9.0	9.0	9.0	9.0	9.0	6.5	9.0	6.5	6.5	6.5	6.5	5.0
	C	8.0	2.0	4.0	5.5	4.5	3.0	4.0	7.0	7.0	4.0	5.0	7.0
	T	26.0	20.0	22.0	23.5	22.5	14.0	22.0	18.0	18.0	15.0	16.0	16.5
Absolute	E	10.0			5.0			5.0	10.0	10.0			5.0
ALL		110	95	102	117	114	83	115	110	110	105	102	84

A-E indicates different respondents, not all respondents answered every criteria question, T indicates total.

"Absolute" refers to one respondent who rated all the problems as a whole, without using specific criteria.

TEST STRATEGIES

The test strategies for this experiment, were developed, using a national survey of design practitioners, to obtain a uniform measure of current opinion, which was then used as a framework for strategy formulation by the experimenter.

A. National Survey Questionnaire

The national survey was based on a questionnaire mailed to individuals prominent in the design methods literature of environmental design and related fields. The purpose of the questionnaire was to present alternative approaches to design strategies in a standard format in order to obtain the most current viewpoints stated in a readily comparable manner.

Materials for the survey were generated as: a) "steps", listing alternative operations which might be included in a design strategy; and b) "assumptions", describing alternative approaches which might be used in formulating a specific set of steps in a design strategy. The steps were based on a synthesis of a number of design strategies (Appendix B-1) with an emphasis on steps which seemed to have a general acceptance, but which indicated basic differences in meaning. A total of 32 steps (Appendix B-2) were identified in the following general categories:

a. Definition
b. Planning
c. Information and Organization
d. Solution Generation
e. Solution Development
f. Evaluation
g. Implementation and Follow-Through

In a similar way, the assumptions were generated from the design methods literature, although in this instance the concepts were usually not stated explicitly and had to be extrapolated on the basis of overall approaches to design strategies. In the final outcome, 19 basic assumptions (Appendix B-3) were generated in the following categories:

a. Strategy Function
b. Design Process
c. Specific Operational Approaches
d. Overall Problem-Solving Approaches

The survey requested respondents to indicate the sequence of steps for an effective design strategy, and to signify their agreement or disagreement with the assumptions which were offered. In both instances the order of presentation was varied from the groupings indicated above, in an effort to break up obvious sets and encourage independent judgments. Forty prospective respondents were identified on the basis of demonstrated interest in design strategies, and questionnaires were mailed to these individuals along with a covering letter of explanation and a pre-addressed and stamped return evelope.

B. Survey Results

A total of 13 respondents, representing important methods areas, responded to the questionnaire. The results are shown on Tables 3-3 and 3-4 and summarized in Appendix B-4. The relevance of the questionnaire was essentially confirmed, since each step and assumption was cited at least once, and most were mentioned four or more times. Typical step results included a) support for the commonly recognized sequence of

"definition", "information gathering and organization", "solution generation", "solution development" and "evaluation"; b) twenty-four of the steps cited by a majority of the respondents, although with no consistent pattern or sequence; and c) an average strategy length of 18 steps, although in some cases steps were combined to approach a 10-step strategy. Most importantly, minority groups of respondents selected specific steps not generally accepted, and suggested sequences of step usage different from the general pattern.

The assumption results confirmed most of the assumptions, with at least minor acceptance for assumptions considered to be more "systematic". An important aspect was the observation that the respondents frequently did not discriminate between assumptions that were intended by the experimenter to be conflicting or contradictory. For example, the "Strategy function" assumptions were intended to represent mutually exclusive approaches, yet some respondents agreed with two or more of these assumptions. Although the responses may have been due, in part, to the phrasing of the assumption statements, it appears that there is a lack of a clear understanding or approach on the part of practitioners, which might be aided by an appropriate display and comparison of these concepts in the test strategies.

Table 3-3 Step Responses on National Survey Questionnaire (numbers represent order of inclusion in strategy sequence)

STEP ALTERNATIVES																
			Definition					Planning				Information				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
A		1	2	2	2	2	3		1	2,3		3,4	1			3
B	13	1	3	5	6	16	15		9	10	11	12	18	7	17	
C																
D	6		1	2	3	4	5	8	9	10	11	12		7		
E	4	1	2	3	8	9	11	5	6	7	10	13	14	17	16	12
F	2	1		3	4	6	5		12	13	14	15				
G																
H	2	2	1	1					3	3	4	5				
I	1				2			4								
J	1				3					4	5			2		
K	2	1		5	6	4	3						7			
L	6	1	3	2	8	5	4	7	10	11	12		9			
M	2		1	2	2	2	2					3	2	4	2	
T	10	7	7	9	10	8	8	4	7	8	7	7	6	5	3	2

	Generation				Development						Evaluation					Imp.
	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
A	4				5		6	6				5	5	5,6	6	6
B		2	8	19	20	21	25	24	19	4		14	22	17	23	25
C																
D					13	15		18	14					16	17	19
E		15	20	23	22	21	24	29	18		25	19	27	26	28	30
F		8	9	10			18		7		17		16	15		19
G																
H		5	5	6	6	6	6	9	6	6,7		9	7	9	9	8
I		5					7	10	3	6	9				8	11
J				6									9	7	8	10
K																
L		13	16	17	19	21		24	18	15		14	22	20	23	25
M		3	8				14	8-13	7	4-7	10	2	13		7	
T	1	7	6	6	6	5	7	8	8	5	4	6	8	8	9	9

A-M indicates respondents; C,G omitted this section; T=total

Table 3-4 Assumption Responses on National Survey Questionnaire

"x" represents agreement with assumption

	ASSUMPTION ALTERNATIVES																		
	Function			Process						Operational						Overall			
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)	(s)
A		x						x							x		x		
B		x				x						x		x					x
C	x	x	x		x	x		x		x	x		x		x		x	x	
D						x		x	x						x		x		
E	x	x		x	x			x		x	x			x					
F	x		x		x						x	x	x		x	x	x		
G	x	x						x				x		x	x		x		
H	x	x	x	x	x	x		x	x				x		x	x	x	x	
I	x	x		x	x	x			x	x	x				x			x	
J			x	x		x	x	x	x		x			x		x		x	x
K		x		x				x	x	x			x				x		
L			x			x			x		x		x		x		x	x	x
M			x		x	x	x	x						x		x	x		
T	6	8	6	5	6	8	2	9	6	4	6	3	5	5	8	4	9	5	3

NOTE: A - M indicates respondents, T indicates total for all respondents

C. Strategy Development

The development of the specific strategies was based on the experimenter interpretation of the survey results, modified by the requirements of the research study. The major experimental consideration was the "comparability" of strategies, requiring the provision of distinct variations which would be likely to produce measureable effects on design performance. The degree of guidance in each strategy was

initially varied by specifying three different lengths or numbers of steps in the strategy sequence. This approach is suggested by the strategies of various lengths as shown in Appendix B-1. Lengths of 5, 10, and 15 steps were selected in order to have comparable numeric differences, while maintaining the strategies within manageable lengths.

The structure and content of the strategies were also varied in ways which might highlight the differences, primarily through developing the strategies in increasing orders of complexity (Appendix B-5). The 5-step strategy presented the simplest, most basic approaches, essentially redefining the major divisions in the design process, and forcing reliance on individual intuitive approaches. The 10-step strategy was based on a more traditional model using the general sequence, and most popular steps and assumptions identified in the survey. The level of detail provided was increased over the 5-step strategy but the 10-step alternative followed the most obvious patterns, and required considerable individual interpretation. The 15-step strategy was developed by the experimenter as a theoretically "best" design strategy, utilizing presumeably more systematic concepts pre-tested and confirmed by at least a minority of respondents in the survey. This strategy included operational instructions for: initiating the problem-solving activity; controlling information relevance; and solution development; providing specific

design aids to guide the subject throughout the design process. The three strategies (Figure 3-1) were then assumed to include differences in length, detail, and technique which would directly affect the quality of design performance.

Figure 3-1 Test Strategy Step Sequence

5-STEP STRATEGY

1. Defining The Problem
2. Gathering Data
3. Developing Preliminary Solution
4. Detailing The Solution
5. Evaluating Solution

10-STEP STRATEGY

1. Determining User Requirements
2. Determining Solution Constraints
3. Gathering Data
4. Organizing Data
5. Developing Conceptual Solutions
6. Developing Subsystem Solutions
7. Developing Overall Solution
8. Detailing Overall Solution
9. Evaluating Solution
10. Revising Solution

15-STEP STRATEGY

1. Identifying Design Task
2. Determining Operational Definition
3. Determining Minimum Limitations
4. Developing Solution Targets
5. Screening Solution Targets
6. Gathering Data
7. Processing Data
8. Identifying Subproblems
9. Developing Subproblem Solutions
10. Integrating Subproblem Solutions
11. Developing Solution System Alternatives
12. Detailing Solution Alternatives
13. Evaluating Solution Alternatives
14. Optimizing Solution
15. Refining Solution

In the final form of the strategies an effort was made to preserve strategy differences while minimizing extraneous factors as follows: a) strategies were not intended to "trick" the subjects, each of the strategies was workable and presented as straight-forwardly as possible; b) roman numerals were used to identify strategy steps in order to highlight the important functions of each single step; c) step titles were kept as uniform as possible between strategies, except for specific differences in meaning; and d) both titles and explanatory definitions were reviewed for clarity and ambiguity.

D. Strategy Hypotheses

Specific hypotheses to be tested in the experiment were developed in terms of assumed differences in the strategies (Appendix B-6), the general hypothesis and subhypotheses are listed as follows:

General Hypothesis: Different strategies will produce significant effects on design problem-solving.

Hyp. 1: The 5-step strategy should generally be more inefficient, producing unsatisfactory solutions.

Hyp. 1-1: The 5-step strategy should require more time for solution.

Hyp. 1-2: The 5-step strategy should require greater effort getting started on problem-solving.

Hyp. 1-3: The 5-step strategy should be highly redundant with information indiscriminately selected and used.

Hyp. 1-4: The 5-step strategy should show significant improvement in efficiency over repeated test sessions.

Hyp. 1-5: The 5-step strategy should produce significantly poor solutions, improving over time.

Hyp. 2: The 10-step strategy should be relatively easy to apply, but should be generally conservative, and somewhat inefficient.

Hyp. 2-1: The 10-step strategy should facilitate the start of problem-solving with little hesitation.

Hyp. 2-2: The 10-step strategy should display considerable redundancy and inefficiency, with a relatively great concentration on details.

Hyp. 2-3: The 10-step strategy should rely on practical considerations rather than conceptual approaches.

Hyp. 2-4: The 10-step strategy should show relatively slight but constant improvement in efficiency over three test sessions.

Hyp. 2-5: The 10-step strategy should produce moderate, traditional, solutions with little improvement over time.

Hyp. 3: The 15-step strategy should be overall the most efficient and effective.

Hyp. 3-1: The 15-step strategy should provide for a direct, effective definition of the problem.

Hyp. 3-2: The 15-step strategy should utilize information selectively, with an efficient problem development.

Hyp. 3-3: The 15-step strategy should concentrate on conceptual information, developing broad solution implications.

Hyp. 3-4: The 15-step strategy should be relatively efficient initially, with little change over time.

Hyp. 3-5: The 15-step strategy should produce consistently high-level solutions with an emphasis on thoroughness and innovation.

INFORMATION BANKS

The development of the three information banks involved: identifying the kinds of information needed, generating information items from the literature, and structuring the information for the subject's use.

A. Types of Information

Major types of information, applicable to the three problems, were identified from the test strategies which, either implicitly or explicitly, direct the subjects toward the acquisition of different types of information and the expression of different concepts. Information needs were determined in the areas of: a) defining the problem; b) developing the problem and solution requirements; c) specifying the final solution. Specific "definition" information mentioned in the strategies includes: 1) user requirements, 2) solution constraints, 3) external constraints, 4) design task descriptors, 5) operational definition statements; covering both detailed and minimum limitations. Problem "development" information is not specified in the strategies, except for the direction to "gather" information, but alternatives commonly identified in the literature (Appendix J) include: 1) user characteristics, 2) user activities, 3) design factors or principles, 4) man-environment research information, and 5) background information on similar problems. "Solution specification" information is identified in the strategies at various levels including: 1) conceptual solutions or solution targets, 2) subsystem or subproblem solutions, 3) solution elements to be included in overall solutions, and 4) solution specifications or element details in final solutions. Evaluation information would not require a separate information type since it would refer back to earlier criteria. Process information would also be needed to indicate

specific techniques or types of relationships used in processing the information.

B. Information Selection

Specific information for the three problems was identified from a variety of sources, most of which would be available to a practicing designer. The different source types are identified in Appendix C-1 and the related literature is cited in the information bank bibliography (Appendix J). However, some source examples are: a) articles, texts, and handbooks, related to environmental design; b) design curriculum materials; c) planning materials used for designing educational facilities. The search for information was as comprehensive as possible. Additional details might have been located, but in most cases these would have been beyond the reach of the typical designer.

The selections of information from these sources were controlled by the experimenter. The experimenter essentially acted as a design practitioner preparing information for his own project, but including an expanded range of information alternatives to allow for different subject approaches. Selection procedures included: a) literally recording information as given; b) screening information for applicability or reinterpreting it in a more useable form; c) fabricating information unique to the experiment (as in the "client" requirements), or unavailible in the literature (new items for

"vending"). This fabrication, however, was kept to a minimum and was always based on general design principles. It should be noted that with the exception of clearly outrageous statements, the information was not checked for accuracy or relevance, since it was assumed that in the real-world the designer is often presented with uncertain information and it is one of the functions of the strategy to aid in dealing with such information.

C. Item Generation

The assembled information was subdivided to form specific information "items" as shown in Figure 3-2. This involved generating: a) lists of single items; b) modified items or brief statements; c) longer statements representing definitions or concepts; and d) drawings of solution elements or typical layouts. Considerations in generating the items included: 1) logical and consistent subdivision of larger concepts; 2) familiarity and understandability of terminology and definitions; 3) ease of combining items into complex expressions; and 4) control of item quantity in each type category to provide a range of alternatives (usually 10-20) without overloading the subjects.

D. Information Structure

The collection of individual items was organized in order to: a) facilitate subject location and use of items; and b) to simplify the coding and interpretation of items.

Figure 3-2 Information Item Card Format

Each item was given a specific location in a hierarchical system including: 1) major information function (using an alphabetic character); 2) specific information characteristics (usually by "tens" digit); and 3) individual item sequence (usually "unit" digit). This informational structure was governed by: a) rough sequence of use, to facilitate location and retrieval; b) randomization of specific use sequences, to minimize probability of a straight sequence of selections; c) randomization of information items within categories, to avoid experimenter bias in determining item importance. Terminology in organizational headings was chosen to maximize identification and recognition, and minimize similarities to terminology used in defining test strategies. Category descriptions are given in Appendix C-2. The main headings used for all three information banks are shown as follows:

Definition Information

A. Problem Descriptors

B. Process Descriptors

C. Overall Requirements

D. Information Requirements

E. General Requirements

Development Information

F. User Types

G. Action Types

H. Design Considerations

J. Research Information

K. General Information

Solution Description

L. General Element Classes

Z. Solution Concepts

W. Graphic Elements

X-Y. Element Specifications

Solution Elements

M-N. Material Elements

O-Q. Furniture Elements

R-S. Equipment Elements

T-V. Ancillary Elements

TEST APPARATUS

The development of the apparatus represented a key element in facilitating the practical application of the experimental materials in a real-life-like setting. The procedure used was to identify a set of working requirements based on the research needs, and then to determine the physical components which would best meet these requirements.

A. Operational Requirements

The major consideration in apparatus design was to permit the subjects to work as naturally as possible, performing a number of different operations as described in Appendix C-3, and listed by major headings below:

1. Information Selection
2. Information Grouping
3. Information Relationship
4. Information Disposition
5. Information Modification
6. Information Consideration

It was considered important to permit all subject operations to occur with a minimum of effort, and with a natural flow of visual and physical movements.

B. Recording Requirements

The apparatus also had to accommodate the recording of specific data required for the information processing protocols, encompassing the following dimensions described in detail in Appendix C-4:

A. Identification

B. Sequence

C. Duration

D. Description

E. Step Behavior

It was important that all of these recording operations should be accomplished as unobtrusively as possible, minimizing subject distractions and secondary task burdens.

C. Practical Requirements

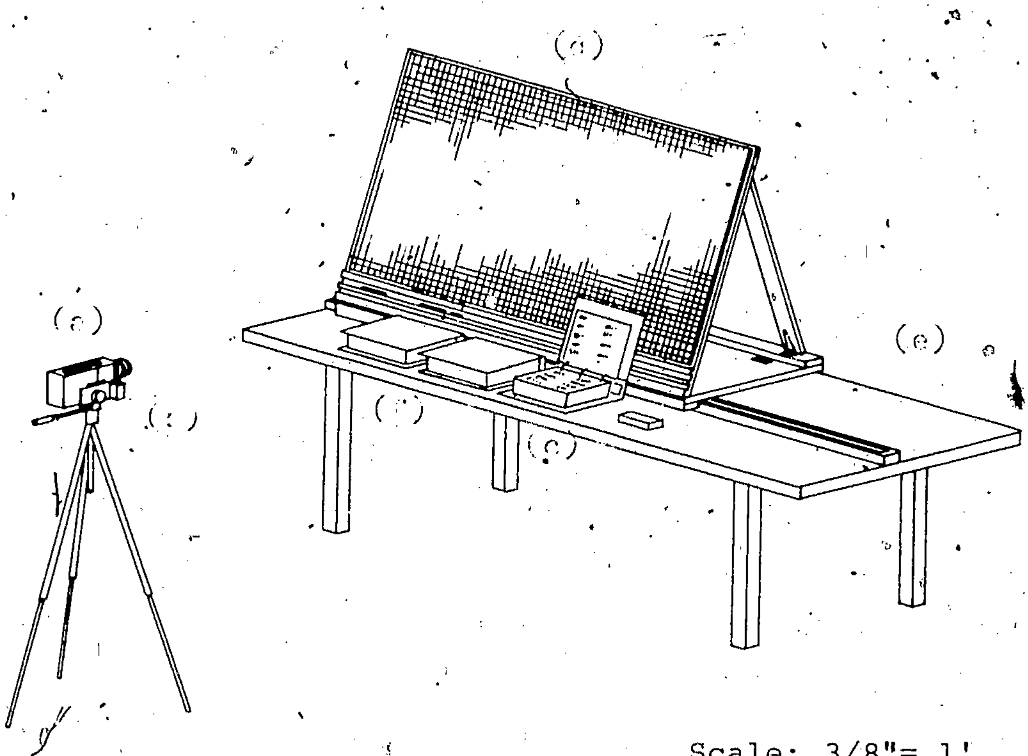
Additional requirements were considered for the best use of the experimenter's efforts and resources, including: a) the use of three sets of apparatus, permitting simultaneous running of three subjects to reduce the amount of time required for testing; b) economy of constructing and transporting multiple sets of apparatus; c) durability of apparatus to withstand repeated useage and handling; and d) minimal dependence on experimenter for apparatus operation. In longer terms, the record produced by the apparatus should be convenient to handle and process in coding and analysis.

D. Design Process Information Recording System (DEPIRS)

DEPIRS (Figure 3-3) represents an integrated set of components adapted to design problem-solving research, which should be ideally suited for this study and readily applicable to future projects. The apparatus development is shown in Appendix D-1, with the detailed specifications in D-2. The basic approach uses physical information cards which are

selected and manipulated by subjects, with a photographic record taken automatically at pre-determined intervals, providing data on information use. The major elements of the apparatus include: a) a 16mm motion picture camera, with b) an attached timing mechanism, operating a single-frame exposure release every 30 seconds, recording the manipulation of c) information items pre-printed on light cardboard backed by a small magnet, which allows them to adhere to d) a 3' x 5' metal chalkboard, resting on e) a removeable base; after the cards are removed from f) a three-ring storage binder with metal pages. Standard chalk and erasers could be used with the items to perform necessary modifications or clarifications.

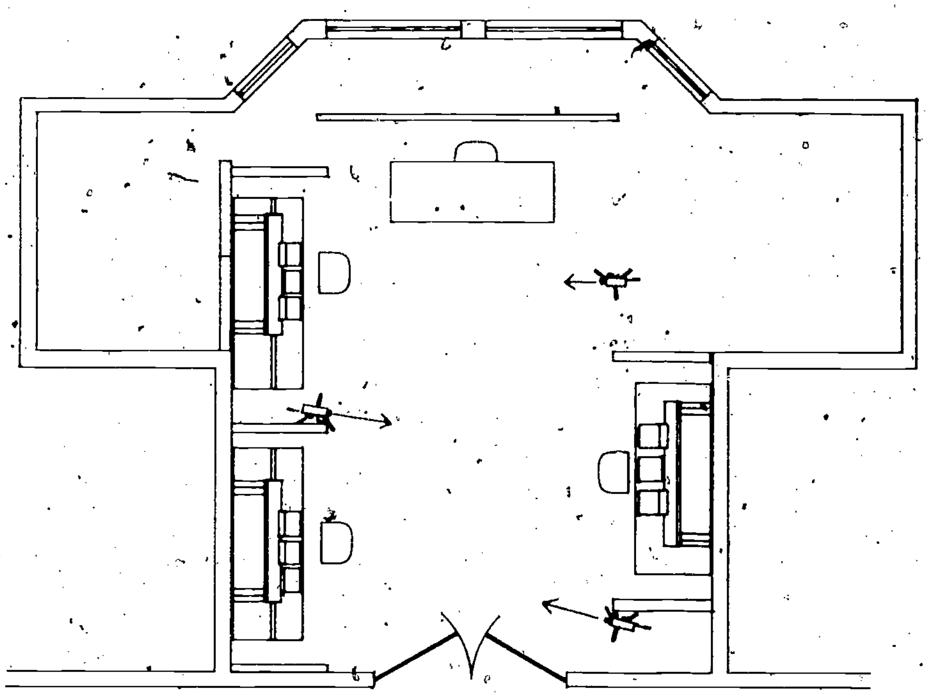
Figure 3-3 DEPIRS Apparatus



Scale: 3/8"= 1'

DEPIRS was designed for use in a classroom at the School of Architecture, UW-Milwaukee (although it could be easily adapted for other locations) which was particularly suited for the experiment (Figure 3-4) with: a) movable display panels which could be arranged to form test "booths"; b) adjustable spotlights to illuminate the display area; c) work tables to support the apparatus; d) chairs for seating; and e) unused alcoves for storing larger apparatus elements between sessions. The apparatus was set up as shown, following the procedures described in Appendix D-3.

Figure 3-4 Test Room Layout



Scale: 1/8"= 1'

TEST SUBJECTS

Subject selection was based on a determination of the characteristics desired in a subject population, identification of a suitable population, and selection of the best possible set of subjects.

A. Subject Requirements

Subjects were previously identified as students trained at an advanced level in environmental design problem-solving. Additional requirements included: a) membership in a sizeable pool from which a uniform subset could be drawn; b) participation in a common standard curriculum; c) some exposure to formal design methods, without being trained in any single strategy or method; d) high motivation to cooperate with a somewhat unique and tedious design task; and e) ability to spend time on three all-day test sessions in addition to orientation and study time.

B. Subject Selection

The nearest available students with suitable characteristics were graduate students at the School of Architecture, University of Wisconsin, Milwaukee (the department on the Madison campus has few students and their backgrounds are very diverse). The students in Milwaukee were reviewed with the aid of a cooperating faculty member to identify individuals who had completed course work related to the scale of the proposed test problems, and who seemed suitable in terms of level of

competance and potential interest. The records of the candidates were reviewed to insure a similarity in: a) undergraduate education, b) graduate program, c) work experience, d) academic performance. Using this information it was possible to identify a matched group of nine subjects with several alternates. The nine students were further divided into three equivalent groups on the basis of the faculty member's class experience with the specific individuals.

C. Subject Recruitment

The motivation of subjects became a major factor in the final recruitment of prospective test subjects. Initially, the experimenter, aware of the effort involved in the experiment, had specified a stipend of $90 for each subject. This seemed to be a substantial inducement, averaging $3/hour for three and a half day's work. However, when the students were informed of the nature of the experiment and the stipend, only six of the nine candidates responded. The experimenter then determined that many of the students held outside jobs with an adequate income and therefore the stipend was not sufficient to induce students to give up time near the end of the semester. Consequently, the stipend was raised to $150, and on this basis the recruitment was satisfactorily completed.

CHAPTER IV - IMPLEMENTATION: Operating Procedures

Introduction:

The procedures used by subjects in the experiment were left up to the individual subject's own working patterns. In contrast, specific procedures were required in attempting to insure a thorough orientation of subjects before the experiment, and in generating meaningful results from the data record after the experiment. Additional procedures demonstrate the experimenter's responsibilities in handling the apparatus, and the method for running the experiment.

SUBJECT ORIENTATION

The orientation of subjects had two main purposes: a) presentation and interpretation of the strategies, to insure that subjects would be able to use a given strategy in practice; and b) familiarization of subjects with the tasks to be performed, in order to reduce accommodation time in the test session.

A. Invitation

A memorandum was used to inform potential subjects of their selection for the study, and to briefly describe the nature of the task and the time committment required. Subjects were requested to contact the liason faculty member to register their acceptance and to request any needed clarification.

B. Orientation Meeting

A meeting was held with the experimenter, the liason faculty member, and six of the subjects to answer questions about the experiment and work on scheduling (additional subjects were handled individually). The experimenter expanded on the information provided in the invitation, avoiding the specific discussion of problems or strategies. The bulk of the meeting was concerned with making decisions to: a) run the test sessions on three consecutive weekends; b) work on saturdays, sundays, and mondays; c) start the sessions at 9:00 a.m.; and d) schedule the weekends within the time remaining in the school term.

C. Orientation Booklet

An orientation booklet was prepared for distribution to subjects one week before the first test session. This booklet provided instructions for the experimental task for use as a reference throughout the experiment. The contents of the booklet are listed below, they essentially presented materials covered elsewhere in this report:

1. Procedure Summary
2. Experiment Overview
3. Design Strategy Introduction
4. Design Strategy Description
5. Information Bank Introduction
6. Information Bank Structure
7. Experimental Apparatus

8. Using Information Items
9. Using Notations (chalkboard)
10. Pretest
11. Tentative Schedule of Test Sessions

A major function of the booklet was the distribution of specific test strategies to their respective users, listing the specific information for each strategy under "design strategy description", while holding the rest of the booklet <u>constant</u>. The largest amount of space in the booklet was used for orienting subjects to specific functional aspects of the experiment. An attempt was made to describe the details as fully and operationally as possible, without making reference to the problem types, in an effort to prevent advance planning or thinking about a specific method of solution.

The pretest was designed to serve as a study aid and to be used in the pre-session orientation as a check on subject comprehension. The test used "matching" and "fill-in-the-blank" questions to verify subject understanding of the design strategy and its applications, and the structure and use of the information banks. Some questions were left open-ended in order to elicit general questions and uncertainties about the materials.

D. Pre-Session Orientation

The experimenter met with the three subjects who would be using the same test strategy on any given test day, at

the start of the test session, taking about one hour on the initial sessions to cover: a) review of the pretest and discussion of the test strategy, with examples and reference to questions raised on the pretest; b) a demonstration of the apparatus and its use, literally paging through the information bank and reviewing the information contained in each section; and c) a brief statement of the problem and a discussion of its implications, stressing an innovative and creative approach.

Pre-session orientations were given on all three weekends with the subsequent sessions taking less time to cover the problem statement and new information. In all the sessions the subjects were encouraged to ask questions, and orientation was continued until subjects appeared confident in comprehending their task. An effort was made to insure uniformity between orientations for different groups, using a standard format, and repeating similar information in the same way.

EXPERIMENT PREPARATION

The preparation for the experiment consisted of working with the apparatus so that it would be fully functional at the beginning of the test sessions.

A. Pilot Test

After fabrication was completed, the apparatus was

assembled for pretesting. The set-up was reviewed to check for completeness and convenience of operation. A graduate student in Industrial Engineering was asked to review the orientation booklet, and then to use the apparatus in an abbreviated test session. The results of this evaluation generally confirmed the applicability of the orientation booklet and apparatus design. Some suggestions were made for the pre-session orientations including: a) clearly explaining the operation of the apparatus, and b) stressing that subjects were not to work competitively. Technical suggestions included: 1) writing descriptive information on the chalkboards to identify each film record, 2) increasing the camera distance to cover a larger work area, and 3) using a formal written log to record subject questions and comments during the test sessions.

B. Transportation

The completed apparatus was transported to Milwaukee two days before the first test session in a station wagon which readily accommodated: the three chalkboards and bases (in a folded position); three tripods; and four boxes containing cameras, information banks (in storage binders) and accessories. The experimenter and one assistant easily loaded and unloaded these materials and installed them in the test site.

C. Set-Up

The apparatus was set-up in the test area following the

procedures detailed in Appendix D-3. The major aspects included: a) clearing and rearranging the test room to accommodate the apparatus, b) placing the larger apparatus items in position, c) unpacking and distributing the materials in the work areas. This procedure lasted only a few hours, with the heavy moving accomplished the previous evening, and the final details completed before the pre-session orientation. The interim use of the room required this set-up to be repeated on each of the test weekends.

RUNNING THE EXPERIMENT

The procedures for running the test sessions were for the most part open-ended, allowing subjects to work out problems in their own way, with a few formal aspects used to maintain experimental control. The overall timing of the experimental session is given in Figure 4-1.

A. Subject Operations

At the conclusion of the pre-session orientation, each subject took a position at one of the test stations and wrote out identification information on the chalkboard. When this was completed, the cameras and timers were started to begin the recording process. Since the timers operated at fixed intervals, no external time-keeping was required.

Once the cameras were started, the subjects began working, usually looking through the items in the information banks, starting with materials related to problem definition.

Table 4-1 Times Recorded for Experimental Sessions

(figures indicate time at which event occurred in each session)

EVENTS	TEST SESSIONS								
	Problem I			Problem II			Problem III		
	SAT 10-st	SUN 15-st	MON 5-st	SAT 10-st	SUN 15-st	MON 5-st	SAT 10-st	SUN 15-st	MON 5-st
Start Set-Up	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00
Start Orient.	11:00	9:45	9:30	9:00	9:15	9:10	9:30	9:15	9:15
Start Testing	11:50	11:15	10:30	9:30	9:45	9:40	9:45	9:30	9:30
Lunch Break	1:05	12:30	12:30	12:30	12:40	12:40	12:35	12:00	12:30
Restart Testing	1:50	1:05	1:45	1:15	1:20	1:40	1:35	12:50	1:45
Winding Break	4:00	3:30	3:15	4:00	--	5:25	2:50	--	--
Restart Testing	4:15	3:45	3:45	4:10	--	5:35	2:55	--	--
End Testing	7:45	7:00	8:00	5:10	5:20	6:15	3:25	4:30	5:00
End Session	8:45	8:00	9:00	6:10	6:20	7:15	4:25	5:30	6:00

"End Testing" represents time at which last subject stopped working on the problem

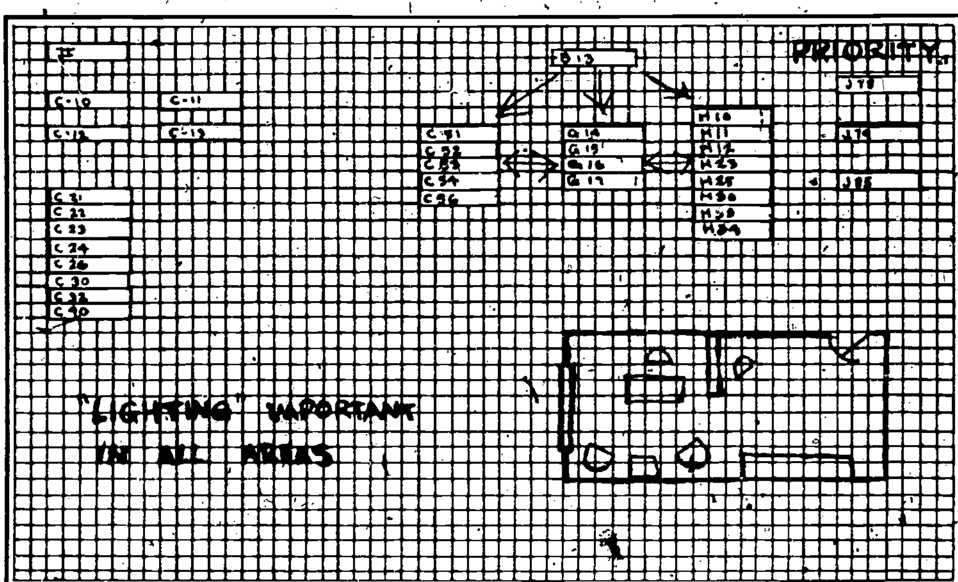
"End Session" represents time at which all cards were replaced in banks, subjects were dismissed, and experimenter completed teardown

Subjects were free to work at their own pace and pattern, within their interpretation of the design strategy. The only formal requirements were that they should indicate the strategy step they were using at any time, placing an appropriate indicator card in the display area; and that on the first prob-

lem they should describe any layout configuration using a standard locational coordinate system (an attempt to standardize data coding).

Typical work patterns consisted of a cyclical sequence of selection, organization, and interrelation of information items; as information was used for: definition, development, and solution specification. Individual differences were possible in terms of the quantity and type of information selected different sequences and configurations, and different use of verbal and graphic notations (Figure 4-2).

Figure 4-1 Typical Information Displays



(a) Strategy Step
(b) Item Selection
(c) Item Grouping
(d) Relationship (Series & General)
(e) Disposition (priority)
(f) Verbal Notation
(g) Graphic Notation

B. Experimenter Operations

The experimenter's major role was as a monitor, supervising subjects and apparatus to guard against accidents or difficulties. The experimenter did not interact with the subjects during the experiment, except for a few brief questions shown in Appendix E-1. The relatively complex camera set-up was checked frequently (Appendix D-3) to insure that the record was being made satisfactorily.

C. Break Periods

A luncheon break of approximately one hour was scheduled, at which time the cameras and timers were stopped. Subjects were cautioned to avoid either looking at each other's work or discussing the experiment during break periods. Both this period and a similar mid-afternoon break were used to rewind the cameras. After each break, all subjects reassumed their positions and the cameras were restarted. Informal, restroom, and stretch breaks, were permitted for individuals, but the cameras remained in operation for these brief periods.

D. End Session

The conclusion of work on the test problem was left to the discretion of each individual subject. Usually the pattern was: a) one subject would announce that his work was completed, b) the camera and timer for this subject would be stopped, c) shortly thereafter the other subjects would conclude their work (this could take as much as an hour),

d) after a given subject had completed his work, he would be requested to return his cards to the information bank.

E. Subsequent Sessions

A similar procedure was followed for all nine test sessions over the three weekends, with some variations: a) design activity started earlier on each successive weekend, b) the afternoon re-winding breaks were omitted in shorter sessions, and c) the coordinate location system was abandoned in favor of direct graphic layouts after the first sessions.

F. Debriefing Meeting

A meeting of the nine subjects was held shortly after the last test session, in order to obtain retrospective observations on the experiment. The subjects were asked a series of questions which are given with their responses in Appendix E-2. The questions covered the following areas:

A. General Impressions

B. Representation of Real Problem-Solving Processes

C. Ability to Follow Test Strategy

D. Difference From Normal Strategy

E. Learning From Experiment

F. Reaction to Information Grouping

G. Reaction to Information Bank

H. Different Ways to do Experiment

I. Reaction to Apparatus and Method

DATA PROCESSING

Once the experiment was completed, the film record gener-

ated in each test session was displayed using a "single-frame" 16mm projector. Data was retrieved by means of a frame-by-frame inspection of the film record. The resulting data was used to generate a variety of "performance" measures, using both machine and manual tabulation.

A. Data Coding

A coding procedure was used to translate observations of subject operations on the film into a form convenient for further processing and evaluation. This coding procedure was developed as a means of effectively and efficiently representing the data in a form suitable for keypunching. The coding methods and "conventions" are described in Appendices F-1 and F-2, essential feature include:

1. Identification
2. Frame Number
3. Strategy Step
4. Information Items
5. Information Status
6. Information Grouping
7. Group Relationship
8. Relationship Type
9. Disposition Type
10. Verbal Type
11. Graphic Type

Using the coding system it was possible to review and code the films relatively easily, noting only changes occurring between frames. The completed coding sheets were submitted to the keypunching service. A total of 17,743 cards were punched and later transferred to magnetic tape.

B. Computer Tabulation

A considerable amount of data was available in terms of: a) information use, b) groupings, c) relationships, and d) modifications; recorded by: 1) time, 2) sequence, and 3) strategy step for each test session. For the purposes of this report, within the time and resource limitations, it was only feasible to use a summary of this data: tabulating total scores for each measure over each entire test session. A program was written to generate frequency counts and related statistics for information item selection, reuse, and groupings. Details are shown in Appendix G-1, major information types are listed as follows:

1. Item Selection (class and subclass totals)
2. Item Reuse (total reuse, total reuse/item)
3. Item Groupings (total groups formed)
4. Grouping Runs (length of group sequences)
5. Total Number of Cards (data)

The program was somewhat complicated due to the number of tabulation listings and statistical functions, but the data could be read by the computer very directly using the item code and group numbers.

C. Manual Tabulation

Manual tabulation of additional data variables was employed due to the relative expense of program writing. This tabulation was based on a print-out of the data cards in an easily readable format (Appendix G-2). Using this method of

hand counting the following measures were obtained:

1. Number of Frames/Session
2. Number of Relationships Formed
3. Number of Disposition Occurrences
4. Number of Verbal Notations
5. Number of Graphic Notations

Although this procedure was time-consuming, the process was simplified by noting only absolute frequency of occurrences rather than specific types within each category. In addition, these variables were by their nature less numerous than the information item data tabulated by computer.

SOLUTION EVALUATION

A separate procedure was used to generate measures of solution effectiveness, based on the solutions as presented in the film record, rather than the item-by-item coding. This process used direct inspection by the experimenter and a jury of expert evaluators to identify and order solution differences.

A. Solution Record

Solution data occurred on the film record in terms of: a) graphic sketches made on the chalkboard, and b) specific information items related to the solution. The graphic images were literally copied from the film, using a projection and tracing technique, including notes and specifications written with the drawings. Related solution information items were usually indicated by their placement or context and their code

numbers were recorded in the groupings shown by the subjects, for later decoding in written form.

B. Solution Format

The solution data was reorganized for presentation to the evaluators and for general reference (Appendix H-3, H4): a) the subject's drawings were re-drafted using a standard format to fit an 8½ x 11" sheet, b) a perspective view was generated by the experimenter from the subject's drawings, c) the square footages of the proposed designs were estimated, and d) a solution specification sheet was generated, listing the solution elements selected by subjects, screened for duplicates, and arranged with informative "element type" headings.

C. Solution Evaluators

A panel of design professionals was used to review the solutions in order to establish meaningful, expert comparisons. Individuals were selected on the basis of their professional standing to include a variety of orientations toward problems of this type, including:

1. Campus architect, UW-Madison, member AIA.
2. Partner, local architectural firm, with prior experience in the design of classroom buildings.
3. Professor, Department of Environmental Design, with experience in educational facilities design, AIA.

These individuals were approached by the experimenter who explained the nature of the evaluation task and secured the cooperation of each person on the basis of their interest,

with a small honorarium for the effort involved. Evaluators were given three weeks to complete their judgments.

D. Evaluation Criteria

Evaluation criteria were generated by the experimenter to assist the professional evaluators in making their judgments, based on considerations commonly applied to design solutions, formulated in terms of the materials available for evaluation (Appendix H-1). Specific criteria titles were:

1. Comprehensive
2. Effective
3. Efficient
4. Aesthetic
5. Innovative
6. Complete

E. Evaluation Package

Materials were assembled and packaged in a looseleaf binder for use by the evaluators, providing explanatory information in a form which would be convenient to handle and review. Major types of information included:

1. Description of the Experimental Task
2. General Instructions for Evaluation
3. Description of the Criteria
4. Listing of General Requirements
5. Listing of Specific Problem Statements and Requirements
6. Nine Solution Drawings for Each Problem
7. Nine Specification Sheets for Each Problem
8. Ranking and Rating Sheets for Each Problem

The general and specific requirement statements (Appendix H-2) were developed directly from the information banks so that evaluators would have available to them the same information given to subjects. The solution drawings and specification sheets were presented front and back in a plastic sleeve so that they could be used together, and could be removed from the binder to facilitate decision-making. The evaluators were not informed of the use of different strategies and the order of presenting the nine solutions for each problem was randomized to eliminate strategy groupings and order effects. Subject solutions were identified only by a code letter representing order of presentation. The evaluation forms provided for a two-step judgment, ranking the solutions to each problem, using pre-printed boxes; then rating the solutions to show relative differences using the code letters written along a continuous line to indicate comparisons with "best" and "worst" expected solutions. The results of this evaluation are indicated in the following section with the other experimental measures.

F. Solution Characteristics

A separate manual procedure was used to generate solution characteristic measures, as an effort to reinforce the evaluations. These measures were tabulated from an inspection of the solution drawings and specification sheets. Details of the development are described in Appendix I-1,

characteristic types included:

1. Number of Elements Listed in Specification Sheets
2. Number of Details Provided in Solution Drawings
3. Estimated Square Footage
4. Number of Room Divisions
5. Number of Functional Room Areas
6. Number of Changes in Floor Level

CHAPTER V - INTERPRETATION: Results and Implications

Introduction:

The experimental results were quite extensive with a large number of individual measures of subject performance and solution quality generated from the experimental data. However, the usefulness of the results in determining the effects of design strategies was limited by the great variation in subject responses within strategy groups and the lack of distinct strategy differences on major measures such as overall information useage, total time required for problem-solving, and overall solution quality. Despite this, there were a considerable number of suggestive differences in the response of strategy groups on specific measures which could be discussed in terms of different strategy characteristics. Based on these suggestive differences and the overall configuration of the results, modified by subject feedback in the debriefing session, it is possible to develop some tentative implications for future research in design methods and for environmental design methods in general.

EXPERIMENTAL RESULTS

The major emphasis of this experiment was on the development of performance measures describing the subjects' use of information while solving the test problems. Consequently, the major part of the results covers measures related to the overall patterns of information use, and the frequency of selection and reuse of information within specific informa-

tion type categories. A much smaller number of measures were generated from the inspection and evaluation of the solutions developed by the subjects. All of the measures are described in detail in the appendix and summarized in the body of the report. An additional type of result, the responses given by subjects in the debriefing session are listed in Appendix E-2.

A. Presentation of Results

In the final results, seventy-one separate measures were generated for use in this report. The distribution of these measures, by category, is shown in Table 5-1. In reading this table it should be observed that category #1 summarizes use characteristics over all types of information, while categories #2 - #5 represent use scores for different types of information. The specific measures within each category are described in Appendix I-1, and individual subject scores

Table 5-1 Distribution of Measures
(figures represent number of measures established in each category)

TYPE OF MEASURE	# OF MEAS.
1. General Performance	15
2. Definition Information	10
3. Development Information	10
4. Solution Description Information	10
5. Solution Element Information	10
6. Solution Characteristics	7
7. Solution Evaluation	9
ALL	71

for each test session are presented in Appendix I-2, following the format described in Figure 5-1. For reference purposes the average scores for each strategy group over all three problems are presented in Table 5-2. This table lists all of the measures with the exception of the overall solution ranking and rating scores which are averaged in the final entry on the table. The measures in the table are identified by abbreviated descriptive title, and specific important measures are further identified in the discussion of specific measures. It should also be noted that the scores for each measure represent frequency counts for the indicated dependent variable, except for the solution evaluation scores in category #7 which represent the average of the evaluators' rankings and ratings, in which "1" was the best possible score.

B. Analysis of Variance

An analysis of variance was applied to each of the measures, in order to determine a statistical measure of significance for different experimental variables. This analysis was used despite the acknowledged high variability in individual subject scores and the lack of statistical power in analyzing responses from a small group of subjects. The usefulness of the test was considered to be its ability to highlight special effects within the mass of data as a basis for further discussion. The anlysis was based on the model shown in Figure 5-1. Using this model, levels of significance could be computed for the effects of: the test

Table 5-2 Average Strategy Scores

(figures represent average strategy score, usually "frequency", on a given measure, averaging three subjects over three problems within a strategy group, see Si on Figure 5-1)

TYPE	MEASURE	STRATEGY 5	10	15
1.1 General Performance	1.1.1 # Items Select.	302	256	199
	1.1.2 # Card Generated	634	768*	580
	1.1.3 # Frames Requrd	832	688	762
1.2 Major Performance	1.2.1 # Items Reused	90	115	92
	1.2.2 # Reuse Occur.	139	215	170
	1.2.3 # Groups Formed	118	147*	97
	1.2.4 # Runs Formed	29	36	28
1.3 Secondary Performance	1.3.1 # Relationships	119	161	75
	1.3.2 # Dispositions	59	111*	86*
	1.3.3 # Verbal Notat.	4	8	11*
	1.3.4 # Graphic Not.	4	4	8*
1.4 Comparative Performance	1.4.1 # Select. Group	68	65	43
	1.4.2 # Reuse Groups	45	79	52
	1.4.3 Aver. Sel. Gp. Sz.	4	4	6
	1.4.4 Aver. Reu. Gp. Sz.	3	3	3

TYPE	MEASURE	STRATEGY 5	10	15
2.1 Definition Information Selection	2.1.1 Problem Descrip	10	6*	8
	2.1.2 Process Descrip	15	3	2
	2.1.3 Overall Req.	23	15*	16
	2.1.4 General Req.	15*	11	10
	ALL	63	35	36
3.1 Development Information Selection	3.1.1 Action Types	25*	19	9
	3.1.2 Design Consid.	36*	26	21
	3.1.3 Research Info.	25	34	24
	3.1.4 General Info.	13	19	14
	ALL	99	98	72
4.1 Solution Description Selection	4.1.1 Element Class	18	17	6
	4.1.2 Solution Concept	32	20	36
	4.1.3 Graphic Elem.	4	6	5
	4.1.4 Element Specs	6	9	2
	ALL	59	52	49

Underlines indicate degree of significance, 1 = .10, 2 = .05, 3 = .01

* indicates a higher level of significance, on one or more individual problems, than shown by underline.

Table 5-2 continued

TYPE	MEASURE	STRATEGY 5	10	15
5.1 Solution Element Selection	5.1.1 Materials	23	13	8
	5.1.2 Furniture	11	14	8
	5.1.3 Equipment	16	17	8
	5.1.4 Ancillary	14*	13	10
	ALL	64	57	34
2.2 Definition Information Reused	2.2.1 Problem Descrip	3	1	7
	2.2.2 Process Descrip	5	0	4
	2.2.3 Overall Req.	7	8	19
	2.2.4 General Req.	0	2	3
	ALL	16	10	33
3.2 Development Information Reused	3.2.1 Action Types	16	29	5
	3.2.2 Design Considd.	14	24	27
	3.2.3 Research Info.	0	27	1
	3.2.4 General Info.	8	11*	12
	ALL	38	90	45
4.2 Solution Description Reused	4.2.1 Element Class	16	22	4
	4.2.2 Solution Concpt	25	29	62*
	4.2.3 Graphic Elem.	1	1	2
	4.2.4 Element Specs	2	6	1
	ALL	44	51	62

TYPE	MEASURE	STRATEGY 5	10	15
5.2 Solution Element Reused	5.2.1 Materials	6	5	2
	5.2.2 Furniture	9	19	7
	5.2.3 Equipment	12	13	5
	5.2.4 Ancillary	11*	8	6
	ALL	38	48	20
6.1 Solution Scope	6.1.1 All Sol. Items	124	108	83
	6.1.2 # Solution Spec	35	36	28
	6.1.3 # Drawing Det.	14	16	13
6.2 Solution Parameters	6.2.1 # Square Feet	11	27	13
	6.2.2 # Room Division	4	4	6*
	6.2.3 # Function Area	8	7	9
	6.2.4 # Level Changes	2	2	2
7.1 Solution Evaluation	7.1.1 Comprehensive	6	5	5
	7.1.2 Effective	6	5	5
	7.1.3 Efficient	5	5	5
	7.1.4 Aesthetic	5	5	5
	7.1.5 Innovative	6	6	4
	7.1.6 Complete	5	6	4
	ALL	33	32	28

strategies acting over the three problems; the interactions between strategies and test problems; the individual test problems themselves; and the variability of the subjects within strategy groups. It should be noted that since the test problems were presented to all subjects in the same order, the effects ascribed to problems may also represent sequence effects. As an additional test, the data for individual test problems was used to determine levels of significance for the effects of strategies on individual problems. However, it was assumed that these results would be less important due to the smaller amount of data involved.

Figure 5-1 Matrix for Analysis of Variance
(indicating data configuration for 27 data records)

	SUBJECTS												
	S1				S2				S3				
	X11	X12	X13		X21	X22	X23		X31	X32	X33		
P1	X111	X112	X113	$\overline{S}11$	X211	X212	X213	$\overline{S}21$	X311	X312	X313	$\overline{S}31$	$\overline{P}1$
P2	X121	X122	X123	$\overline{S}12$	X221	X222	X223	$\overline{S}22$	X321	X322	X323	$\overline{S}32$	$\overline{P}2$
P3	X131	X132	X133	$\overline{S}13$	X231	X232	X233	$\overline{S}23$	X331	X332	X333	$\overline{S}33$	$\overline{P}3$
	$\overline{X}11$	$\overline{X}12$	$\overline{X}13$	$\overline{S}1$	$\overline{X}21$	$\overline{X}22$	$\overline{X}23$	$\overline{S}2$	$\overline{X}31$	$\overline{X}32$	$\overline{X}33$	$\overline{S}3$	$\overline{X}$

MODEL: Xijk = $\overline{X}$ + Si + (SP)ij + Pj + Uk(i) + (UP)kj(i)

Xijk = individual score on a given measure

$\overline{X}$ = overall average

Si = test strategy (S1 = 10-step; S2 = 15-step; S3 = 5-step)

Pj = test problem (P1 = Office; P2 = Snack Bar; P3 = Conf. Rm.)

(SP)ij = strategy-problem interaction

Uk(i) = subjects within strategies

(UP)kj(i) = Error

Xik = individual subject using a given strategy

$\overline{X}$ik = average score for individual subject over all problems

$\overline{Si}_i$ = average score for each strategy over all problems
$\overline{Si}j$ = average score for each strategy on a single problem
$\overline{P}j$ = average score for each problem over all strategies

C. Significance of Results

The outcome of the analysis of variance is summarized in Table 5-3 and the respective levels of significance are indicated on Table 5-2 and on the individual results tables in Appendix I-2. The most important observation is that even including significance at the .10 level, the overall strategy effect was demonstrated on only 8 out of 71 measures.

Table 5-3 Distribution of Significance

(figures indicate number of measures which display a given level of significant difference for each variable)

SIGNIFICANCE	EXPERIMENTAL VARIABLES					
	Strategy Overall	Strategy /Problem	Strategy xProblem	All Strategy	Problem	Subjects W/In St.
.01	2	2	8	12	13	30
.05	4	6	10	20	7	16
.10	2	8	6	16	12	4
EST	(12)	(0)	(0)	(12)	(0)	(0)
ALL	20	16	24	41*	32	50

NOTE: "EST" represents measures which displayed consistent strategy overall differences based on inspection of the data, but below statistical significance

*indicates total number of measures which displayed strategy differences, adjusted for overlapping variables

This result is statistically within the area of a random distribution of effects. Additional strategy effects were shown for indi dual problems, but again the number is small

as compared with the total measures. The effects of strategy interaction with problems were somewhat more numerous, suggesting the possibility of some difference between strategy groups. However, these interaction effects are difficult to define and still affect only a minority of the measures. This overall low level of significance is modified slightly by a grouping of the different types of strategy significance with measures where some effects were estimated but not statistically significant. This grouping includes over half the measures but at best can only serve as an indicator of possible significance confounded by other experimental variables. In particular, the effects of individual problems and variability of subjects within the strategy groups appear to have had as much if not greater influence.

The lack of significant strategy effects is further emphasized by referring to Table 5-2 and noting the lack of significant differences for most of the overall performance measures in category #1, and the absence of significance for solution measures in categories #6 and #7. Even in measure <u>1.1.3 # Frames Required</u> (by definition, twice the number of minutes required for problem-solving), the apparent significant difference in time was based on a highly abbreviated third test session by the 10-step strategy group, attributed to subject misunderstanding of the experimental task. The strategies therefore did not appear to demonstrate effects on the measures of overall information use, amount of time or effort

required for solution, nor were the solutions produced by the different strategies significantly different. The initial, basic conclusion is that the experiment was not successful in demonstrating comparative differences between strategies.

EXAMINATION OF MEASURES

Each of the measures was examined by inspection, after the initial analysis of variance, to determine if any suggestive differences were present that might contribute to a better understanding of the results. The examination concentrated on measures where some level of significance was present, but also included measures where consistent differences could be observed by ignoring the scores of at most one subject in each strategy group. This latter approach represented even lower levels of significance, but did make some allowance for the high variability in subjects. In conducting the examination, the emphasis was on interpreting apparent differences in terms of the meaning of the measures and their interaction with the experimental variables. This was largely based on the experimenter's experience in developing the experimental materials and a general background in environmental design. The purpose of the examination was not to force conclusions in the absence of meaningful significance, but rather was included to demonstrate some of the capabilities of the experimental method and raise some questions for further experimentation.

A. Problem Results

The effects of the test problems on different measures were important because of the attempt to control the selection of problems in order to minimize problem effects, and because problem effects operated across strategy groups providing a basis for comparing specific strategy differences. The differences in average problem scores are shown in the individual measure tables in Appendix I-2, but the summary of types of effects for different numbers of measures is provided in Table 5-4. This table indicates problem effects in various different configurations. The most prevalent configuration was a descrease in the scores between problems. This decreasing effect does not appear to be due to the problems themselves, since there is no obvious tie-in with problem characteristics, but rather appears to indicate a sequence effect over the three test sessions. The assumption is that the subjects became more selective in their utilization of information and related activities due to an increased familiarity with the experimental task. However, this may also represent a lower level of motivation with repetitions of a similar task. Specific measures demonstrating this effect and possible interpretations are given below:

<u>1.1.2 # Cards Generated</u> - shows a steady drop between each of the three test sessions (p=.01), perhaps due to greater efficiency in information handling.

Table 5-4 Distribution of Interaction Effects

(figures indicate number of measures on which a given variable displayed an effect with a given configuration)

CONFIGURATION		VARIABLES						
Type	Session	Problem	Strategy Perform.			Strategy Solution		
			5	10	15	5	10	15
I-III SAME	All Steady	7	6*	0	1*	0	0	3*
	II Down	4*	2	3	13*	0	0	0
	II Up	8*	3	5	5	0	0	0
	ALL	19*	11*	8	19*	0	0	3*
DECREASING	I-II Down	16*	3*	10*	0	4*	0	0
	II-III Down	8*	2*	6	2*	0	0	0
	I-II-III Down	9*	1*	8*	0	2*	0	0
	ALL	33*	6*	24*	2*	6*	0	0
INCREASING	I-II Up	2*	0	0	1*	0	3*	0
	II-III Up	0	0	0	0	0	0	2*
	I-II-III Up	1*	0	0	0	0	2*	0
	ALL	3*	0	0	1*	0	5*	2*

NOTE: Interaction effects occur when a given variable influences the data in definite direction over the three test sessions (I, II, III); for strategies the interaction represents a direction taken by one strategy, while the other two strategies move in a different direction

* indicates that a majority of the measure displayed a significant interaction effect at least p=.10

For Strategy Solution, a decreasing direction indicates that the solutions are improving

1.1.3 # Frames Required - indicates a major drop between the second and third sessions (p=.10), suggesting that although the level of information processing decreased from session I to II, the discrimination required additional time.

The individual measure groups reinforce the decreasing pattern with 3.1.5 All Development Information Selected and 4.1.5 All Solution Description Information Selected showing a steady decline over three problems (both, p=.10). In addition the drop in Frames is paralled by 3.2.5 All Development Information Reused (p=.15).

There was also a noticeably different response given on problem II, apparently due to subject interpretation of the Snack Bar as a larger scale problem than the other two. The effect is first noticed on 2.2.3 Overall Requirement Information Reused, which increased in frequency in comparison to problems I and II, although not significantly, suggesting that more effort was required to define the more complex problem. This effect is reinforced by a similar pattern for 4.1.2 Solution Concept Information Selected, apparently indicating a corresponding increase in solution complexity. The assumption is also supported by a decrease in 5.1.2 Furniture Elements Selected and 5.1.3 Equipment Elements Selected (p=.01, .10), which might be expected where these elements were less important at the larger scale. The scale assumption is literally confirmed by the relatively higher levels shown in 6.1.3 # Drawing Details, 6.2.1 # Square Feet, 6.2.2 # Room

Divisions, 6.2.3 # Functional Areas (p=.05, .10, .10, .05).

B. Performance Results

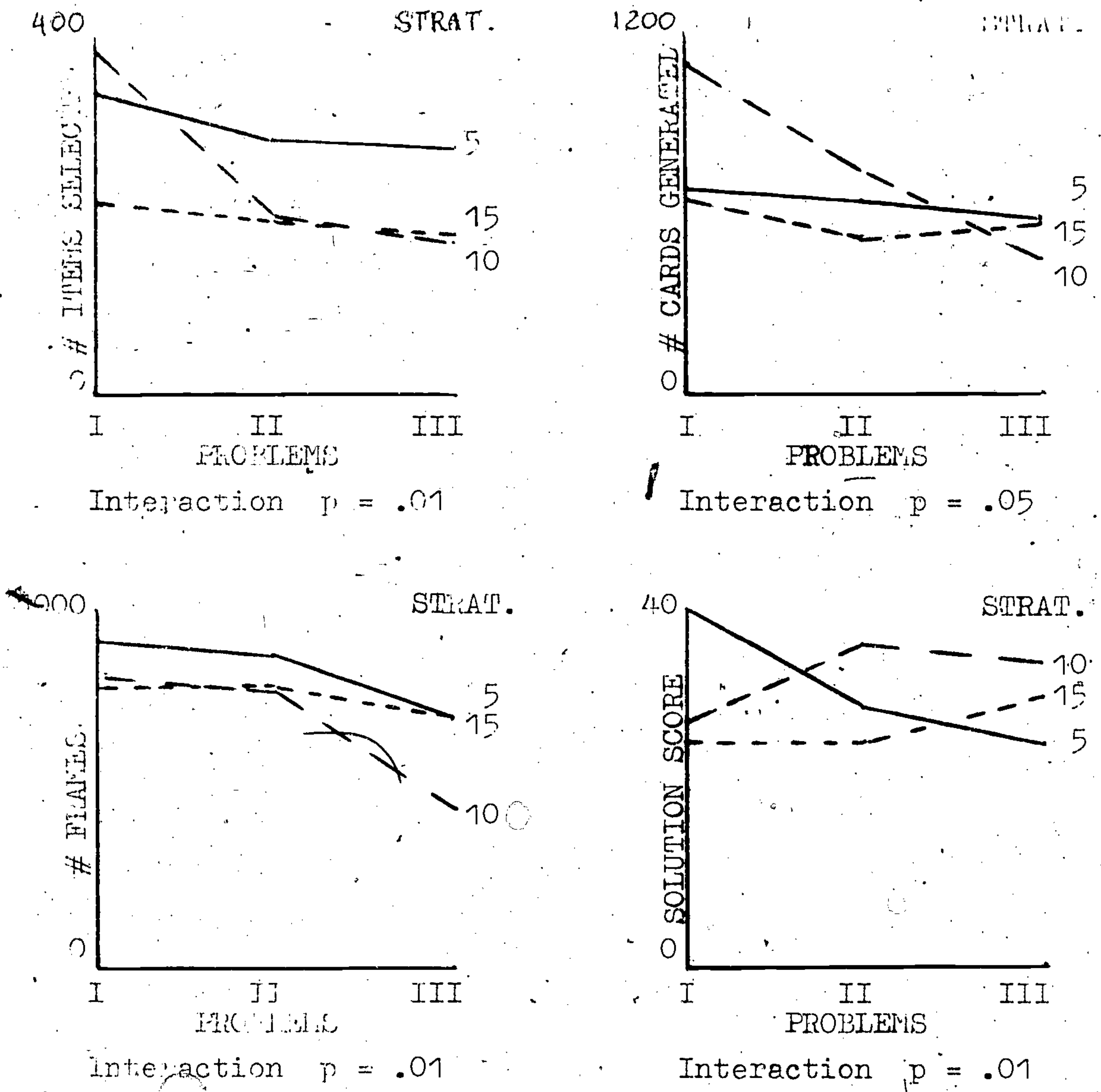
The effects of strategies on problem-solving performance, while lacking strong significance, did display a number of differences which could be related to the characteristics of the specific strategies. The effects for strategies over all problems are indicated in the average scores shown on Table 5-2. Strategy-problem interactions are based on the strategy averages for each problem shown in Appendix I-2, and key relationships are represented in Figure 5-2 and in Appendix I-3. The range of strategy-problem interaction configurations is shown on Table 5-4. Important measures related to overall performance, problem-solving information, and solution element information are described below with possible interpretations:

1. Overall Performance Measures (Category #1)

These indicate a number of strategy differences affecting overall performance, demonstrating different basic strategy approaches.

1.1.2 # Cards Generated - The 10-step strategy tended to generate more data cards than the other strategies on all three problems, although the effect was only significant on problem I (p=.10). This represents a high level of activity on all measures. Similar effects appeared on 1.3.2 # Disposi-

Figure 5-2 Typical Strategy-Problem Interactions



tions, (p=.05), reflecting a large amount of activity with individual item cards; and 1.2.3 # Groups Formed (I, p=.10), indicating a large selection and reuse of items (see 1.4.3, 1.4.4). The impression is that the 10-step strategy tends to encourage greater concern with detail in handling information.

The effect of the 10-step strategy is also apparent in the problem interaction on this measure, with the 10-step showing a dramatic decrease in the number of cards used, as much as 300 cards between each session, while the other strategies remained steady (p=.05). This pattern is repeated on # Dispositions, # Groups Formed, and 1.2.4 # Runs Formed (p=.05, .10, .10). The pattern is particularly evident for 3.1.5 All Development Information Selected (p=.01). The suggestion is that some initial confusion resulted in very high activity on the first problem, with a second re-evaluation taken after the second problem.

The 15-step strategy demonstrates an alternative interaction effect on this measure, with a slight but noticeable drop in activity between problems I and II and then a rise back up again on problem III. This pattern generally occurs on various measures in parallel with the 10-step steady decrease, particularly on Dispositions, Groups, and Runs. Examples of the pattern on specific measures include: 3.1.2 Design Consideration Information Selection (p=.01); 3.2.4 General Information Reused; and 3.2.5 All Development Information Reused (p=.05) In comparison with the "Problem Results", these suggest that the low number of data cards for

the 15-step on problem II may be due to a sensitivity to scale with a simpler development used for the larger scale problem.

1.1.1 # Information Items Selected - The drop in overall activity for the 10-step strategy is repeated on this measure between problems I and II, with the other strategies steady (p=.01). This reinforces the assumption that the 10-step group made an essentially random selection of information on the first problem, which was corrected on problem II. A similar pattern occurrs on 1.4.1 # Selection Groups Formed (p=.05), and the area of impact is indicated by the non-significant but distinct repetition of the pattern on 2.1.5 All Definition Information Selected, and 3.1.5 All Development Information Selected.

1.1.3 # Frames Generated - The 5-step strategy required noticeably more time to complete the design task, particularly as compared with the 10-step strategy (p=.01). In comparison to 1.1.2, this suggests that the 5-step strategy was less efficient, requiring more time to accomplish less information processing.

The interaction effect on this measure shows that the 15-step strategy remained relatively steady over all three problems, while the 5 and 10-step strategies showed a major decrease in frames between II and III (p=.01). Since the

frames for the 15-step were initially low, it is possible that the other strategies were developing more efficient procedures over the three sessions.

This assumption is reinforced in part by 1.3.4 # Graphic Notations, where the 15-step was noticeably high on problem I (p=.05), despite experimenter attempts to limit graphics in favor of a "coordinate" system. The suggestion is that the 15-step group completed highly developed solutions on I, which required graphic expression. In addition, 1.3.3 # Verbal Notations showed a relatively high level for the 15-step on problem III (p=.10), raising the possibility that the 5 and 10-step groups oversimplified their procedures by the third problem, while the 15-step was still operating at high levels of complexity.

2. Problem-Solving Information (Categories # 2-4)

These measures indicate different responses to information types or categories, including both selection and reuse of information in each session. Specific information differences suggest clues to basic strategy philosophy and approach.

2.1.1 Problem Descriptor Information Selected - The 10-step strategy was low overall on this measure, particularly for problem III (p=.10). This type of information was used to define the problem in general terms before beginning the detailed definition, and the low utilization suggests a less structured approach to problem definition. The effect is reinforced by 2.1.3 Overall Requirement Information Selected,

which was very little used by the 10-step group on problem III (p=.10), apparently reflecting an oversimplified definition on this problem. In contrast, the 15-step group was noticeably high overall on 2.2.1 Problem Descriptor Information Reuse, particularly as compared with the number of these items selected, suggesting a greater concern with formulating the initial definition.

2.1.2 Process Descriptor Information Selected - The 5-step strategy was very high on this measure, with the other strategies showing negligible scores (p=.05). This information type was unique, listing alternative design "techniques" or "heuristics" rather than problem information, and the assumption is that the 5-step group was uncomfortable with their open-ended strategy and used this information to further clarify their design activities.

A parallel effect showed the 5-step group with a significantly high score on 2.1.5 All Definition Information Selected (p=.01), suggesting that in general the strategy used a more diffuse search process in attempting to define the problem. This is supported by the high level shown on 2.1.4 General Requirement Information Selected (III, p=.05), an information type which was considered to be marginally relevant, and was included in the information bank primarily for the sake of completeness.

3.1.1 Action Type Information Selected - Both 5 and 10-step strategies were high overall on this measure, with the 5-step particularly high (p=.05). This effect is important since this information type simply lists alternative activites which might take place in the problem environment, and concentration on an activity-by-activity analysis seems to be an inefficient, mechanical approach in a limited problem-solving session. It should be noted that the 10-step group tended to be very high on Reuse (3.2.1) of this information, indicating that the items received more than casual attention. A similar effect is evident on 4.1.1 Element Class Information Selected, with both strategies relatively high on this listing of alternative general types of solution elements, suggesting a more dogged, empirical approach.

4.1.2 Solution Concept Information Selected - In contrast with the above, the 10-step strategy was low overall on this measure (p=.10), which includes conceptual statements describing a variety of solution approaches and dimensions. This information allowed subjects to sketch out solutions in general terms before beginning detailed development, and the low utilization confirms the more pedestrian approach. Although the 5-step strategy was high on this measure, 4.2.2 Solution Concept Information Reused, shows a much higher level of application for the 15-step group. In particular, a significantly high score for Reuse on problem I (p=.10) suggested that the 15-

step subjects were able to comprehend and utilize this information much earlier than the other strategies.

3.1.5 All Development Information Selected - The 15-step group was generally low overall on this measure, although high subject variability prevented significance. The assumption is that the 15-step approach was more economical and selective of information used in development, with a high dependence on overall conceptual information. In comparison, the 10-step strategy was high on this measure and particularly high on 3.2.5 All Development Information Reused. ($p=.05$), and 3.2.4 General Information Reused (II, $p=.10$). The impression is that the 10-step spent considerable amount of effort on "busy work", since the "research" information was only marginally useable given the time and scale limitations; and the "general" information was largely concerned with previous traditional solutions. It should be noted that the 10-step group did not make correspondingly high use of Design Consideration Information (3.1.2, 3.2.2), considered by the experimenter to be the most relevant design development information.

3. Solution Elements (Category #5)

Although the selection and reuse of solution element information did not show many significant strategy effects, there were some indications of differences in this area.

5.1.2 Furniture Elements Selected - The 15-step strategy displayed the sensitivity to problem effect mentioned earlier with a noticeably low score on this measure for problem II, and an increase on III, while the other strategies remained the same between problems II and III (p=.05), presumeably de-emphasizing furniture at the larger scale. This assumption is supported by 5.2.2 Furniture Elements Reused, on which the 15-step had an average score of "0" on II.

An inverse effect for this strategy was noted on 3.1.3 Research Information Selected, where the 15-step was noticeably higher on II, presumeably indicating layout and perceptual information applied to the problem. Another indication of sensitivity differences was observed in the interactions on 4.2.2 Solution Concept Information Reused, where the 15-step used fewer concepts on II, while both the 5 and 10-step groups increased their useage on II. Apparently, the other strategies responded to the change in scale by making greater use of more general concepts, while the 15-step simplified its approach (Note: the 5 and 10-step strategies showed only minor "sensitivity" responses, see Table 5-3).

5.1.4 Ancillary Elements Selected - The 5-step strategy displayed significant interaction effects on this measure, increasing in use between all three problems, while the other strategies were steady or decreasing (p=.05). This is made particularly evident by significantly higher levels for

the 5-step on problem III for both <u>Selection</u> and <u>Reuse</u> (5.2.4) (p=.05, .10). The information type represents a concern with spatial enclosure and mechanical systems, less central to solution development, and the assumption is that the 5-step group ignored or minimized these aspects due to uncertainties about solution formulation on the earlier problems, and later increased in confidence and was able to explore the solution in greater depth.

C. Solution Results

The two attempts to compare solutions, by measures of different characteristics, and by expert evaluation, had been intended to demonstrate differential strategy effects. However, the results indicated considerable uniformity between strategy groups, particularly in comparison with the variations in problem-solving performance. The examination in this area, therefore, is based on the possible implications of relatively slight differences between scores.

1. Solution Characteristics (Category #6)

These measures were developed in an attempt to identify objective differences in the solution approaches taken by subjects in different strategy groups. Due to the general uniformity in solution drawings and specifications, there were very few meaningful differences in this area. A minor interaction did occur on <u>6.1.3 # Drawing Details</u> where the 5-step strategy remained steady while the other strategies

increased in detail on II, presumeably in response to scale. Another measure, <u>6.2.2 # Room Divisions</u> showed the 15-step strategy high on problem III ($p=.05$) suggesting the maintenance of a high level of complexity on the final problem.

2. Solution Evaluation (Category #7)

The solution evaluation measures, generated by a professional jury of evaluators, were intended to provide a comprehensive comparison between the solutions produced by subjects in different strategy groups. However, the results of the evaluation were inconclusive, the evaluators themselves were highly variable and the results of their evaluation as shown in Table 5-2 and Appendix I-2 averaged out to very similar scores well below significance. Despite the questionable significance, observation of the data does suggest that the 15-step group may have produced slightly better solutions, both in terms of all criteria: <u>7.2.1 All Criteria Ranking and Rating Combined</u>; <u>7.2.2 All Ranking Criteria</u>; and <u>7.2.3 All Rating Criteria</u>; and specific measures: <u>7.1.2 Effective</u>, <u>7.1.5 Innovative</u>, and <u>7.1.6 Complete</u>. Thus there is some suggestion that the 15-step strategy is more useful; providing effective, workable solutions, although not necessarily superior in comprehensiveness or efficiency; maintaining an innovative solution approach (as stressed in the problem statement); and maintaining a complete, thorough solution specification.

Interactions on the evaluation were significant (Figure 5-2), with the 5-step strategy showing a definite improvement over the three problems (for all criteria), while the 10-step showed worse scores after the first problem, and the 15-step was steady to slightly worse on the last problem (p=.01). The assumption is that the 5-step demonstrated a learning effect, while the 10-step produced acceptable results only with the greatest level of activity. The 15-step displayed relative consistency after starting rather successfully, and the drop in quality on the final problem may have been due to the evaluators misinterpreting the high level of solution complexity which was continued by this strategy (in accordance with experimenter's definition of the problem), while the other strategies simplified their final solutions.

D. Subject Results

The variability of subjects within strategy groups apparently was a major factor in lowering the level of significance for the strategy effects. The extent of the variability is shown in Table 5-5, which indicates that all subjects varied uniquely from the other members in their groups on at least some measures, and that the direction of the difference in frequency scores and evaluation scores was seldom consistent. This suggests a high level of essentially random, personalized interpretations of the problem and strategy within individual subjects. However, an examination of some

specific subject behaviors may help in understanding some of the strategy group scores.

A particular subject effect was apparent in the evaluation of the solutions. For all criteria, subjects within strategies were significantly different (p=.01), in particular, two of the subjects using the 15-step strategy were considered to be very successful (compared with all other subjects, with only one subject in the 5-step group as successful), while the third subject scored very poorly also in comparison with all other subjects). It is possible that the two subjects actually represented the effectiveness of the strategy, while the third subject (with an unusual approach, described below) was misinterpreted by the evaluators.

Table 5-5 Distribution of Subject Effects

	STRATEGY PERFORMANCE								
Difference	5-Step			10-Step			15-Step		
	1	2	3	1	2	3	1	2	3
HIGH	3*	3*	19*	2*	5	21*	4*	4*	12*
LOW	3*	9*	3*	2*	4*	6	1*	6*	15*

	STRATEGY SOLUTION								
Difference	5-Step			10-Step			15-Step		
	1	2	3	1	2	3	1	2	3
HIGH	1*	1*	0	1*	0	0	0	0	5*
LOW	0	0	1*	0	0	0	5*	3*	0

NOTE: * indicates that the majority of the measures displayed a significant subject effect at least p = .10

For Strategy Solution, a low score indicates a "better" solution

The third subject in the 15-step group also displayed unique and significant differences in selection and reuse of two major types of information, scoring very high on problem-related information (generally p=.05), while having low or negligible scores (averaging 4 items to the group average of 52) for solution element information (p=.01). While this may be explained in part by an over-concern with problem development, the accompanying solution graphics suggest a very comprehensive solution rendered in general terms.

Additional subject effects indicate general strategy group trends, consistent in themselves, carried to extremes by individual subjects. Thus, one subject in the 10-step group showed an extremely high reuse level particularly for various types of development information (usually p=.01); while one subject in the 5-step group displayed consistently high levels of selection for all information types (usually p=.01). These confirm major strategy effects and suggest ways in which individuals might have disallowed significant effects.

E. Debriefing Results

The debriefing session, after the running of the experiment, offered the only introspective response from the subjects and was directed to responses to the experimental format rather than the effect of strategies. In general, the responses shown in Appendix E-2, suggested that the experi-

mental task was accepted for the most part by the subjects. The basic approach, using the information bank and test apparatus, seemed to be workable with minor revisions. Although there were some reservations about the artificiality of the experimental situation, there seemed to be overall agreement, or at least lack of strong disagreement, that the experiment was able to accurately reflect design problem-solving and utilization of strategies.

CONCLUSIONS

The conclusions drawn from this experiment can only be general and suggestive. The high variability in the summary data does not permit conclusive judgements about strategy differences. The larger mass of data on the details of problem-solving has not yet been processed, and while this may add a better understanding of design activity, it is also likely to be highly variable. Despite the high experimental and subject variability, tentative directions are discernible, indicating implications for further research. (An asterisk * after a word indicates that the statement did have statistical significance at least at the 5% level.)

A. Suggestive Strategy Differences

Given that a statistically significant difference was not obtained among the strategies, some actual differences observed in the examination of measures can be expressed as suggestive conclusions. They are specifically compared to the experimental hypotheses listed on pages 38-39.

1. General Hypothesis

The actual number of strategy differences and the consistency of the differences in line with hypotheses about strategy effects suggest that strategy significance is masked by subject variability. Strategy differences are apparent throughout the average strategy scores (Table 5-2), and pronounced differences were evident in strategy-problem interactions (Table 5-4). Although not statistically significant, the differences are too numerous to ignore entirely.

2. 5-Step Strategy

An apparent low level of effectiveness for this strategy was demonstrated in part by the additional time required for arriving at a solution, and the apparently random selection and application of information. Overall, the subjects did require more time for solution*, particularly as compared with the 10-step strategy group (Hyp. 1-1). The subjects did demonstrate an apparent uncertainty in beginning problem-solving with a relatively high selection* of definition information (Hyp. 1-2). Although it was not anticipated, the extensive use of process descriptors* to supplement the strategy steps, clearly distinguished this strategy group. The quantity of information selected by this group was not noticeably higher than the 10-step strategy, although the average number of selections were somewhat greater (Hyp. 1-3). By contrast, this strategy did not show much change in efficiency (decrease in selections) over time, particularly as compared with the 10-step (Hyp. 1-4). The solutions produced by this strategy did improve over time*, particularly between

problems I and II (Hyp. 1-5). However, the solution quality appeared competitive or superior to other strategies after the first problem. This strategy did appear to operate better than had been anticipated, in many ways similar to the 10-step, but some difficulty was shown in handling information and in the development of solutions.

3. 10-Step Strategy

This strategy portrayed an apparent uneven performance with an overconcern about details. This is suggested by the overall high levels of activity. Little difficulty was noted in the initial phase of problem-solving with a relatively conservative selection and reuse of definition information (Hyp. 2-1). In general, this group displayed a considerable amount of activity with a high number of data cards generated and a high reuse of information, particularly in more peripheral type categories (Hyp. 2-2). Subjects did show a low use of conceptual information, particularly as compared with overall high levels for other categories (Hyp. 2-3). Improvement in efficiency (decrease in activity) was clearly demonstrated* although at much higher levels than anticipated, suggesting a superficial treatment in later problems (Hyp. 2-4). The data generally indicates low levels of solution quality for this strategy, and inspection of solutions suggests their more conservative aspect (Hyp. 2-5). However, the decrease in quality between problems I and II was not anticipated, and suggests an additional factor of disillusionment or overconfidence. This strategy, then, representing a highly typical approach, is apparently workable, but it

produces only a moderate level of performance.

4. 15-Step Strategy

This hypothetically best strategy was slightly but consistently more efficient and effective in comparison with the other strategies. These subjects appeared to establish systematic definitions as indicated by a substantial selection of problem descriptors and a generally high level of definition activity (Hyp. 3-1). The subjects did indicate lower levels of information selection in most categories, particularly those less central to problem development (Hyp. 3-2). In contrast, the subjects did show high levels of selection and use of conceptual information (Hyp. 3-3). The subjects did remain relatively steady on most measures, with allowance for the response to scale differences on problem II (Hyp. 3-4). The solution ratings were slightly but consistently better, particularly on specific criteria such as comprehensiveness and innovativeness, which had been stressed in the problem statements. These results suggest that this is a definitely workable strategy with potential advantages that could be explored in further study.

B. Research Approach

Additional general conclusions may be reached in terms of the overall approach to design methods research and experimental technique demonstrated in this study. These are important because of the pilot aspects of this research in attempting to indicate a new area for experimental study.

The ability to perform design methods research appears to be strongly supported, if not conclusively established by this

study. The review of literature and related research indicating the need for this type of research were reinforced by the national survey of design strategies which indicated both a level of common understanding about design strategies, and a significant variation in responses and conceptualizations which could be resolved by objective study. In addition, the acceptance of the test strategies by the subjects, and the suggestive differences in performance by strategy groups indicate possibilities for further experimental studies. This study, then, despite the problems with variability, does not diminish the relevance of design methods research.

The experimental task itself did appear to be useful in studying the design process and the effects of strategies, although further refinements are indicated. In most cases the subjects were able to function well using the information banks to develop an understanding of the test problems and develop meaningful solutions. This approach does appear to generate a considerable body of useful data on design performance which can be used to demonstrate and compare the effects of design methods.

A particular question was raised about the effectiveness of the techniques for evaluating the subjects' design solutions. The quantitative measures of solution characteristics did not seem to adequately describe or distinguish between the different solution configurations. The subjective evaluations also did not appear to be consistent in establishing solution quality. There is apparently a need for the development of more refined

techniques for solution evaluation both for experimental and practical purposes.

DISCUSSION

The major issue raised in this study is the variability in subject performance which occurred despite extensive attempts to produce controlled, differentiated behavior. The experimenter attempted to select a highly uniform group of subjects, provide a constrained set of test problems, utilize a standard information bank and experimental task, while using specifically distinct strategy guidelines. Despite this effort, the differences between subjects within the strategy groups were overwhelmingly more significant than the differences between the groups using different strategies. In other words, even in a relatively limited problem-solving situation, subjects using identical strategies did not generate statistically uniform scores on a large percentage of measures.

The explanation for this variability is not clear at this time. One explanation would suggest that the design strategies by their nature have a negligible effect on design performance. This does not seem consistent with the observed suggestive strategy differences. An alternative explanation would be that individual strategy interpretations and ingrained personal design styles confounded the strategy effects. This would be consistent with the generally accepted concept of the design task as an individual, intuitive, creative act. In this case, a given strategy would likely be implemented only partially by the subject, utilizing aspects which were compatible with the subject's

personal approach, and rejecting or reinterpreting conflicting concepts.

The problem for the design methodologist is therefore to develop strategies which can be accepted by individual designers and to present strategies in a manner which is understandable and useable. The design methods researcher must insure that the methods being studied are actually implemented by the subjects, and that indicative differences in performance are captured by the experimental technique.

A. Design Methods Research

The results of this research should not discourage an interest in the study of design methods, but should rather stimulate further attempts to develop useful techniques for investigating the impact of alternative methods on the design process. In this regard, the results to some degree support the utility of the present approach with further refinements.

Subject variability would be a major concern in further refinements, and could be treated in a number of ways. Some variability could be controlled with a more extensive orientation and training program to insure that subjects could and would use the test methods. Patterns of variability associated with different methods could be identified using larger groups of subjects. More sensitive performance measures could be designed to identify specific effects, with problem formats developed to permit greater extremes of behavior.

In other areas, the time and effort limitations for subjects could be reduced by designing apparatus with more convenient

means for information presentation and manipulation, possibly involving some form of mechanical assistance. The information data could be supplemented by an expanded graphic capability and some form of "thinking aloud" technique for recording verbal comments. The information items themselves could be modified to cover different aspects of environmental design problem-solving as well as problem-solving in fields such as Urban Design, Product Design, Machine Design, Industrial Engineering.

With appropriate modification this basic approach could also be used for investigating a range of problem-solving behaviors. Comparisons of methods could be used with alternative strategy configurations, as well as different heuristics and decision-making techniques. Basic information processing could be studied in terms of types of information, forms of information presentation, alternative options for information manipulation. In addition, more fundamental studies could be made of the psychological and cognitive aspects of design problem-solving.

In the immediate future, more specific extensions of this study could also be considered including:

1. Further analysis of the already collected data in terms of the dynamics of information processing within the test sessions, identifying patterns of information useage associated with each strategy step.
2. Additional experimentation using a simplified experimental task, with more extensive training and a larger subject group to increase the consistency of results.
3. Development and experimental comparison of refinements

in the 15-step strategy, using different strategy and problem variations to determine the most effective combination of steps and procedures for environmental design.

B. Design Methods Implications

In a larger sense, this study and further research in design methods should lead to a better understanding and application of design methods by practitioners in environmental design and related fields. To the extent that differences between design strategies were indicated, they present a challenge to traditional assumptions about the negligible effects of methods and the essential similarity of alternative methods. If real differences can be identified between alternative methods, then it is important to search for the best possible methods, testing and comparing methods of all kinds to determine their applicability for problem-solving. In particular, the suggestive results of this study appear to support the proponents of more "systematic" methods, stressing detailed, operational procedures, directed toward a whole-problem viewpoint, with a controlled application of problem-solving information.

The possibilities for establishing meaningful differences between design strategies also present a challenge to design educators in terms of identifying the most appropriate design methods and presenting them as effectively as possible to design students. This suggests the need for a more formalized design methods curriculum involving a comparative analysis of alternative methods and their applications to different aspects of

design information processing. In more general terms, this study indicates the importance of understanding how information is used to generate a final solution, and suggests teaching approaches, using information banks, and recording detailed information protocols, as a means of demonstrating and reinforcing problem-solving behavior.

The broadest implications of this research go beyond the concern with specific design methods or techniques to a consideration of the entire design process. This study is intended to serve as one aspect in the development of a comprehensive science of design, directed toward making the best possible use of the designer's resources in producing the best possible design product. The underlying assumption of a design science, supported in part by this research, is that design is a rational activity which can be made explicit and that through study and understanding the efficiency and effectiveness of design activity can be significantly improved.

BIBLIOGRAPHY

1. Alexander, C., "Information and an Organized Process of Design", Proceedings of the Building Research Institute, Spring, 1961, pp. 115-124.

2. Alexander, C., Notes on the Synthesis of Form, Cambridge, Harvard University Press, 1964.

3. Alexander, C., "Houses Generated by Patterns", Berkeley, Center for Environmental Structure, 1969.

4. Alexander, C.; Ishikawa, S.; Silverstein, M.; "A Pattern Language which Generates Milti-Service Centers", Berkeley, Center for Environmental Structure, 1968.

5. Alger, J. R. M.; Hays, C. V., Creative Synthesis in Design, Englewood Cliffs, N. J., Prentice-Hall, 1964.

6. Ameral, S., "On the Mechanization of the Creative Process", IEEE Spectrum, 3, April, 1966, pp. 112-114.

7. Archer, L. B., "What is Good Design", Design, May, 1960, pp. 28-33.

8. Archer, L. B., "A Systematic Method for Designers", reprint from Design, London, 1965.

9. Archer, L. B., The Structure of Design Processes, London, Longmans, 1970.

10. Asimow, M., Introduction to Design, Englewood Cliffs, N. J., Prentice-Hall, 1964.

11. Banham, R., "Chill Dawn in Colorado", Industrial Design, August, 1965, pp. 38-41.

12. Barnett, J., "Changing Patterns in a New Age", Architectural Record, July, 1966, pp. 249-250.

13. Blake, J. E., "Design by System", Design, April, 1962, p. 39.

14. Bloom, B. S.; Brodel, L. J., "Problem-Solving Processes of College Students", Suppl. Educ. Monogr., No. 73, Chicago, University of Chicago Press, 1950.

15. Borko, H., ed. Computer Applications in the Behavioral Sciences, Englewood Cliffs, N. J., Prentice-Hall, 1962.

16. Buhl, H. R., Creative Engineering Design, Ames, Iowa, Iowa State University Press, 1960.

17. Burnette, C. H., "A Linguistic Structure for Architectonic Communication", in Coates and Moffett, 1969, pp. 101-120.

18. Campion, D. G., Computers in Architectural Design, N. Y., Elsevier, 1968.

19. Cheetham, D., "Training Design Co-ordinators", Design, September, 1964, pp. 40-41.

20. Clarkson, G. P. E.; Pounds, W. F. "Theory and Method in the Exploration of Human Decision Behavior", Industrial Management Review, 5, 1963, pp. 17-28.

21. Coates, G. J.; Moffett, K. M., eds., Response to Environment, North Carolina State University, Student Publications of School of Design, 18, 1969.

22. Corkill, P. A.; Guenter, R. F., "A Systematic Approach to Design", American Institute of Architects Journal, December, 1968, pp. 75-77.

23. De Groot, A. D., "Perception and Memory Versus Thought: Some Old Ideas and Recent Findings", in Kleinmuntz, 1966, pp. 19-50.

24. Dixon, J. R., "Design and Analysis: A Conflict of Interest", Journal of Engineering Education, 54, 7, March, 1964, pp. 243-245.

25. Dixon, J. R., Design Engineering: Inventiveness, Analysis and Decision, N. Y., McGraw-Hill, 1966.

26. Duncker, K., "On Problem-Solving", Psychological Monographs, 58, Whole No. 270, 1945.

27. Eastman, C. M., "Search Strategies for Space Planning", Pittsburgh, Institute of Physical Planning, Carnegie-Mellon University, 1969.

28. Eastman, C. M., "On the Analysis of Intuitive Design Processes", in Moore, 1970, pp. 21-37.

29. Eder, W. E., "Definitions and Methodologies", in S. Gregory, 1966, pp. 19-31.

30. Feldman, J., "Computer Simulation of Cognitive Processes", in Borko, 1962, pp. 336-359.

31. Fetter, W. A., Computer Graphics in Communication, N. Y., McGraw-Hill, 1965.

32. Forehand, G. A., "Epilogue: Constructs and Strategies for Problem-Solving Research", in Kleinmuntz, 1966, pp. 355-383.

33. Frischmuth, D. S.; Allen, T. J., "A Model for the Description and Evaluation of Technical Problem Solving", IEEE Transactions on Engineering Management, EM-16, 2, May, 1969, pp. 58-64.

34. Geddes, R. C.; Spring, B. P., "A Study of Education for Environmental Design", (AIA Report), Princeton University, 1967.

35. Goode, H.; Machol, R. E., Systems Engineering: An Introduction to the Design of Large-Scale Systems, N. Y., McGraw-Hill, 1967.

36. Gordon, J. J., Synectics, N. Y., Collier, 1968.

37. Green, B. F. Jr., "Current Trends in Problem Solving", in Kleinmuntz, 1966, pp. 3-18.

38. Gregory, C., The Management of Intelligence: Scientific Problem-Solving and Creativity, N. Y., McGraw-Hill, 1967.

39. Gregory, S. A., ed., The Design Method, N. Y., Plenum Press, 1966.

40. Guilford, J. P., The Nature of Human Intelligence, N. Y., McGraw-Hill, 1967.

41. Gutman, R., "Site Planning and Social Behavior", Journal of Social Issues, 22, 4, October, 1966, pp. 103-115.

42. Handler, A. B., "The Place of Social Science in Architecture", Architectural Science Review, 7, 4, December, 1964, pp. 124-135.

43. Hellmuth, J., ed., Cognitive Studies, Volume 1, N. Y., Bruner/Mazel, 1970.

44. Jay, L. S., "A Systematic Approach to Problems of Town and Regional Planning" in Jones and Thornley, 1963, pp. 11-22.

45. Jay, M., "Environmental Design: An Introduction", Design, February, 1967, pp. 44-48.

46. John, E. R.; Miller, J. G., "The Acquisition and Application of Information in the Problem-Solving Process", Behavioral Science, 2, 1957, pp. 291-300.

47. Jones, J. C., "A Method of Systematic Design" in Jones and Thornley, 1963, pp. 53-73.

48. Jones, J. C., "Design Methods Compared", Design, August, 1966, pp. 32-35; September, 1966, pp. 46-52.

49. Jones, J. C.; Thornley, D. G., eds., Conference on Design Methods, N. Y., MacMillan, 1963.

50. Kaiser, C. H., An Essay on Method, New Brunswick, Rutgers University Press, 1952.

51. Kitts, L., "A Comprehensive Perspective for the Planning and Design Disciplines", in Krampen, 1965.

52. Kleinmuntz, B., ed., Problem Solving: Research Method and Theory, N. Y., Wiley, 1966.

53. Krampen, M., "Design as Creative Problem Solving" in Krampen, 1965, pp. 3-19.

54. Krampen, M., ed., Design and Planning, N. Y., Hastings House, 1965.

55. Maier, N. R. F., "Reasoning in Humans II. The Solution of a Problem and Its Appearance in Consciousness", J. Comp. Psychol., 12, 1931, pp. 181-194.

56. Maldonaldo, T., "The Emergent World: A Challenge to Architectural and Industrial Design Training" Ulm Journal, 12/13, 1965, pp. 2-10.

57. Maldonaldo, T., "How to Fight Complacency in Design Education", Ulm Journal, 17/18, 1966, pp. 14-20.

58. Malone, R., "Essential Design", Industrial Design, February, 1960, pp. 56-59.

59. McCrory, R. J., "The Design Method in Practice", in S. Gregory, 1966, pp. 11-19.

60. Meister, D.; Farr, D. E., "The Methodology of Control Panel Design", Wright-Patterson AFB, Ohio, September, 1966.

61. Meister, D; Farr, D. E., "A Further Study of the Use of Human Factors Information by Designers", Canoga Park, Calif., Bunker-Ramo Corp., 16 March, 1967.

62. Miller, G. A.; Galanter, E.; Pribram, K. H., Plans and the Structure of Behavior, N. Y., Holt, 1969.

63. Mitroff, I. I., "Simulating Engineering Design: A Case Study on the Interface Between the Technology and Social Psychology of Design", IEEE Transactions on Engineering Management, EM-15, 4, December, 1968, pp. 178-187.

64. Mitroff, I. I., "On the Social Psychology of the Safety Factor: A Case Study in the Sociology of Engineering Science", University of Pittsburg, Graduate School of Business, 1969.

65. Moore, G. T., ed., Emerging Methods in Environmental Design and Planning, Cambridge, MIT Press, 1970.

66. Musgrove, J., "The Dangers of Scientism", Architectural Review, July, 1966, pp. 9-11.

67. Nadler, G., Work Design: A Systems Concept, Revised Edition, Homewood, Ill., Richard D. Irwin, 1970.

68. Newell, A.; Shaw, J. C.; Simon, H. A., "Elements of a Theory of Human Problem-Solving", Psychological Review, 65, 1958, pp. 151-166.

69. Newell, A.; Shaw, J. C.; Simon, H. A., "Report on a General Problem-Solving Program", Santa Monica, Calif. Rand Corp., 1959.

70. Newell, A.; Simon, H. A., "Computer Simulation of Human Thinking", Science, 134, December 22, 1961, pp. 2011-2017.

71. Paige, J. M.; Simon, H. A., "Cognitive Processes in Solving Algebra Word Problems", in Kleinmuntz, 1966, pp. 51-119.

72. Pare, E.; Lyman, F.; Kimbrell, J., Introduction to Engineering Design, N. Y., Holt, Rinehart, 1963.

73. Passonneau, J. "In Search of Theory IV", Arts and Architecture, April, 1965, pp. 24-25.

74. Price, D. J. deS., Science Since Babylon, New Haven, Yale University Press, 1961.

75. Pye, D. W., The Nature of Design, N. Y., Reinhold, 1964.

76. Ranstrom, D.; Rhenman, E., "A Method of Describing the Development of an Engineering Project", IEEE Transactions on Engineering Management, EM-12, September, 1965, pp. 79-86.

77. Reitman, W., "The Uses of Experience: Open Statements, Ill-Defined Strategies, and Intelligent Information Processing", in Hellmuth, 1970, pp. 210-229.

78. Roe, P. H.; Soulis, G. N.; Handa, V. K., The Discipline of Design, Boston, Adlyn and Bacon, 1967.

79. Roylance, J. F., Engineering Design, N. Y., Pergamon Press, 1966.

80. Siders, R. A., etal., Computer Graphics; a Revolution in Design, N. Y., American Management Association, 1966.

81. Simon, H. A., The Sciences of the Artificial, Cambridge, MIT Press, 1969.

82. Starr, M. K., Product Design and Decision Theory, Englewood Cliffs, N. J., Prentice-Hall, 1963.

83. Studer, R. G.; Stea. D., "Architectural Programming, Environmental Design and Human Behavior", Journal of Social Issues, 12, 4, 1966, pp. 127-136.

84. Thomas, E. L., "Problem Solving in Design", in Krampen, 1965, pp. 1-2.

85. Thornley, D. G., "Design Method in Architectural Education" in Jones and Thornley, 1963, pp. 37-52.

86. Van der Ryn, S., "Problems and Puzzles", American Institute of Architects Journal, January, 1966, pp. 37-42.

87. Wason, P. C.; Johnson-Laird, P. N., Thinking and Reasoning, Baltimore, Penguin Books, 1968.

88. Whitfield, P. R., "Report on Visit to America to Discuss Creativity in Engineering, June 17-July 15, 1968", Institution of Mechanical Engineers.

89. Wilson, W. E., Concepts of Engineerings System Design, N. Y., McGraw-Hill, 1965.

90. Zwicky, F.; Wilson, A. G., eds., New Methods of Thought and Procedure: Contributions to the Symposium on Methodologies, N. Y., Springer-Verlag, 1967.

APPENDIX A TEST PROBLEM DETAILS

These appendices describe the details involved in the selection of test problems, including the three sets of selection criteria used in questionnaires presented to the committee members, and a description of the twelve problem alternatives presented to the committee on the final selection questionnaire.

Appendix A-1 Initial Problem Selection Criteria

This lists the criteria as presented on the "criteria review questionnaire", with accompanying descriptive material relating to the selection and application of each criterion. Note that the criteria were grouped by characteristics in this appendix, but were presented to the committee in the order shown by the alphabetic characters in parentheses.

TEST PROBLEM SELECTION CRITERIA	
CRITERIA	DESCRIPTION
GENERAL CONSIDERATION:	Related to overall problem characteristics, requirements for experimentation.
<u>Environmental in Character</u> (B) can this problem be solved as an environmental design task. Does the problem relate to a specific topic area involving a complete range of environmental elements and interrelationships, forming a total living or working environment, relatively complete in itself and separable from other larger environmental systems.	Used as a check and a definition to insure that problems do in fact represent typical environmental design tasks.
<u>Availability of Background Information</u> (C) is it likely that background information for this problem is relatively easily available. Is this an area that has likely been the object of concern and study in the past such that sufficient information would be available in the literature. Are the factors involved ones that can be straight-forwardly researched and interpreted for the problem	A mechanical consideration to insure that material for the "information banks" could be relatively easily developed.
SUBJECT CONSIDERATIONS:	Needs of subjects as interpreted from the evaluator's background.
<u>Motivates Subjects</u> (D) is this problem likely to be of interest to the student. Is there enough variety and challenge, are the questions involved relevant to human and educational concerns such that the student will be motivated to call upon his full creative powers and attempt to produce the best possible solution. Are the materials generated in connection with this problem likely to be of future social use.	An attempt to insure full and enthusiastic cooperation of subjects on this difficult task.

TEST PROBLEM SELECTION CRITERIA continued

CRITERIA	DESCRIPTION
Understandable to Subjects (E) can this problem be defined in such a way that subjects can be able to understand generally what needs to be done and to determine an appropriate solution. Are the concepts involved generally familiar, can a coherant environment be visualized from the problem description.	A check based on the assumption that some problems might be more readily grasped than others.
Reasonable to Expect Solution Within Time Constraints (G) can this problem be solved, following a reasonable procedure, within the time allowed (8 hours). Is this problem reasonable in terms of the number of variables involved, number of activities to be considered, variations in tasks and types of people involved, difficulty in determining a solution.	A practical check on the scale and scope of the problem compared with typical problem-solving abilities.
RESEARCH CONSIDERATIONS:	Utility of the problems in terms of research goals
Permits Wide Range of Solution Possibilities (F) is this problem sufficiently complex and non-clearcut that different problem-solving approaches, definitions, understanding, and sequences of operation are likely to require subjects to make significant decisions and produce distinctly different solutions. Are significantly different solution alternatives possible.	A check on problem flexibility to insure the influence of strategy effects if present.
Comparable to Other Problems (A) is this problem likely to be comparable to other problems that might be selected. Is there equivalent: relative difficulty, familiarity to subjects, number of variables to be considered, similarity of elements or element classes; such that elements of one problem may be generally compared to parallel aspects in other problems.	A necessary consideration if results of the three problems are to be compared for consistency of effects, learning etc.

Appendix A-2 Revised Problem Selection Criteria

This lists the criteria as provided to the committee on the "criteria rating questionnaire", many of the criteria were repeated from the first questionnaire, but were given revised definitions to improve understanding; based on the results of the first questionnaire, "understandable to subjects" was dropped from the list, since it was assummed to be under experimenter control; "permits wide range of solution possibilities" was also dropped in favor of "comparability of solutions within problem area" as listed below; "uniqueness of problem was also added.

TEST PROBLEM SELECTION REVISED CRITERIA

CRITERIA	DESCRIPTION
A. COMPARABLE TO OTHER PROBLEMS Is this problem area likely to be comparable to other problem areas which may be selected? EX: In the problem is there equivalent amount of information to be considered, number and range of environmental variables associated with the general scale of environmental setting, expected familiarity to average college student?	A restatement of criterion on first questionnaire.
B. ENVIRONMENTAL DESIGN TASK Does this problem represent a typical environmental design task? EX: Is the problem setting: a relatively coherant environmental system, a system which includes a typical range of environmental considerations and elements; likely to be generalizeable to other related types of environments or settings?	Restatement of criterion.
C. AVAILABILITY OF BACKGROUND INFORMATION Will the experimenter be able to locate sufficient meaningful information to be presented to the subject? EX: Is this problem area: one that is likely to have been researched in the past, related to other areas which have been researched, primarily composed of elements which have been researched?	Restatement of criterion.
D. MOTIVATES SUBJECTS Will the subject be motivated to call upon his full creative powers and attempt to produce the best possible solution? EX: Is the problem indicated: one for which a common solution has already been accepted, one that is likely to have some impact in terms of human well-being, one that presents challenging difficulties in determining a solution?	Restatement of criterion.

TEST PROBLEM SELECTION REVISED CRITERIA continued

CRITERIA	DESCRIPTION
E. REASONABLE TO EXPECT SOLUTION WITHIN TIME CONSTRAINTS	
Can the subject proceed from the problem statement, through the design process, to arrive at some coherent solution, within the time allowed (8 hrs)? EX: Is the problem to be considered: manageable in terms of scale or number of variables, capable of being handled without interpreting excessive amounts of technical or potentially unfamiliar information, familiar enough that solutions can be determined straightforwardly?	Restatement of criterion.
F. COMPARABILITY OF SOLUTIONS WITHIN-PROBLEM AREA	
Will the solutions produced by subjects for the same problem area be similar enough to permit comparison of problem-solving or strategy variables? EX: Can the desired area of problem-solving be: unambiguously defined, lead to a relatively constrained set of solution alternatives, be straightforward enough that subjects can identify the solution space without the need for wild speculation or unnecessary digressions.	New, a check that the results obtained from various treatments of the same problem, can be compared in the data analysis.
G. UNIQUENESS OF PROBLEM	
While generally comparable, is the problem area different or unique with regard to other problems such that subjects will not simply review or rework solutions produced in earlier experimental sessions? EX: Does the problem area suggest: different alternative sets of information to be considered, a different set of solution variables to be selected, different activities or functions for which a different design task is required?	New, a qualification on criterion # A., while problems should be similar, they should not be too similar.

Appendix A-3 Final Problem Selection Criteria

This lists the criteria as presented on the evaluation sheets in the "problem selection questionnaire", five criteria were used from the second questionnaire, with "environmental design task" and "uniqueness of problem" controlled by the experimenter in generating problem alternatives and placing them in the three major groupings. In this list the criteria are accompanied by "cue" statements which were located on the evaluation sheet at intervals representing high (1), middle (2) and low (3) values on the linear scale.

TEST PROBLEM SELECTION FINAL CRITERIA

CRITERIA	CUE
Comparable to Other Problems	1. The problem has a great many features similar to problems in the other two sets, or a comparable match can be made with selected problems in the other two sets. 2. The problem has some similar features and some differences in comparison with other problems in the other two sets. 3. The problem is considerably different from other problems which might be selected from the other two sets.
Availability of Background Information	1. The problem space is an important one in the university and the design of this space has been discussed extensively both formally and informally in Design and Education literature, or this is similar to other problems in business or industry which have been studied extensively. 2. This problem space is usually taken for granted in the design of university and other facilities and is treated only generally in the literature. 3. This problem space is of no particular interest or is so new or unique in concept that it has been given no specific mention in the design or educational literature.
Motivates Subjects	1. The functions associated with this space are considered by students to be important, or personally relevant to them, and the problems associated with developing a satisfactory design solution are likely to be challenging. 2. The functions associated with this space are usually taken for granted, and the solution is likely to be just a rearrangement of standard elements.

TEST PROBLEM SELECTION FINAL CRITERIA continued

CRITERIA	CUE
	3. This problem is generally considered to be trivial or of no interest to students in the university, about all that is possible is some minor reworking of the standard solution.
Time Constraints	1. While reasonably challenging, and requiring a comprehensive solution, the size of the problem, number of variables, etc., should reasonably permit subjects to solve the problem within 8 hours. 2. The problem is somewhat complex involving a number of functions and subsystems for which there might be some difficulty in finishing within 8 hours. 3. The problem is highly complex with many interacting subsystems or so open-ended or unfamiliar to subjects that it would be very difficult for subjects to organize the material and come up with a solution in 8 hours.
Comparability Within Problem	1. While there is no obvious solution, the nature of the problem is such that almost all alternative solutions should contain enough points of similarity to permit comparison. 2. The problem is somewhat more open-ended in nature and solutions may be significantly different to the point that there may be difficulty in comparison. 3. The problem could be solved in a number of widely divergent ways; permitting little or no comparison.

Appendix A-4 Test Problem Alternatives

This lists the alternative problem statements which were provided to the committee on the "problem selection questionnaire", subdivided into their different groupings. The statements are accompanied by descriptive material indicating the basis for the groupings and the individual problem generations.

TEST PROBLEM ALTERNATIVES

PROBLEM STATEMENTS	DESCRIPTION
I.	Work areas for single individuals, representing an important aspect of higher education facilities, emphasizing specific functions and activities and individual needs.
A. This space should provide office facilities for one teaching faculty member. Primarily this space will be used for desk work involving reading, preparation of lessons, personal correspondence, with a limited use of files, journals, and reference books. Accommodation should be made for one or two visitors, students, grad students or other faculty engaged in review of work or other materials and some limited individual instruction.	Represents a "Faculty Office" a highly typical environment in classroom building.
B. This space should provide office facilities for one administrator whose job involves a great deal of student contact. The use of the space will be roughly divided between desk work and interviews. Primarily the desk work will involve reading different materials with some dictation and telephoning, and might involve limited, mostly interim filing and a few references. Interviews will usually be with one to four students, consisting usually of informal discussion with some shared viewing of materials and form preparation.	Represents an "Administrative Office", an alternative configuration, with more emphasis on students as interviewees.
C. This space should provide office facilities for two individuals, a researcher and one assistant. The space will generally be used for different desk work activities with either individual frequently absent from the space. Desk work will involve reading, review of materials, writing, dictation, or typing using extensive files, journals, and other reference materials. Accommodation	Represents a "Research Office" a somewhat more complex alternative with added personnel and functions.

TEST PROBLEM ALTERNATIVES continued

PROBLEM STATEMENTS	DESCRIPTION
should also be made for regular conferences with four to six participants engaged in discussion, note taking and review of materials, some graphic or other audio-visual aids may be employed.	"Research Office" cont'd.
D. This space should provide office facilities for four graduate student teaching assistants. The space will usually be used for desk work activities including reading books and papers, grading, preparation of lessons, and the student's own studying. Limited resources of reference materials and possibly typing or calculating machines may be shared by the four TAs. Periodic, one or two visitors will generally be students, but may include other grad students or faculty engaged in review of materials or individual instruction.	Represents a "Teaching Assistant Office", involves additional space, treated as a reflected plan for the 4 work stations with some common facilities.
II.	Work areas for small groups, increasingly important in new approaches to education, emphasis on group interaction and communication aids.
E. This space should provide meeting/instructional facilities for various numbers and combinations of faculty and graduate students in a general relationship to departmental offices. The major use of the space will be for departmental meetings or conferences or small informal seminars involving discussion and note taking with some graphic or audio-visual aids. Secondary uses might include eating lunches or other recreational activities, card-playing etc., or individual studying or recreational reading.	Represents a "Departmental Conference Room", another highly typical facility, with assumption that room needs more than a chalkboard, table, and chairs.

TEST PROBLEM ALTERNATIVES continued

PROBLEM STATEMENTS	DESCRIPTION
F. This space should provide instructional/demonstration facilities in connection with a laboratory used for instruction in chemistry, physics, etc., for a faculty member and/or teaching assistant and from ten to fifteen students. This space will be used for primarily lecture-demonstrations with some informal discussion and note taking. Provision should be made for wet and dry demonstration experiments and limited audio-visual aids.	Represents a "Laboratory Discussion Room", a more specialized, technical alternative.
G. This space should provide instructional facilities for a faculty member or teaching assistant and from ten to twenty students participating in discussion sections or seminars. The general use of space will be for a combination of lectures and group discussions for note taking and some graphic aids and display of student work. Other uses may include reading, writing, working on problems and individual instruction either at the student's or instructor's work area.	Represents a "Teaching Discussion Room", another major needs area, includes some aspects of classroom design.
H. This space should provide facilities for experiencing (viewing, listening) a variety of audio-visual aids involving an instructor, a technician, and from five to fifteen students. The primary emphasis will be on providing for the presentation and experiencing of a variety of media including slides, film, television, tapes or their combinations. Secondary uses may include note taking during and after the presentation and informal small group discussion.	Represents an "Audio-Visual Presentation Room", a highly specialized, technical alternative.
III.	Less formal work areas for dining and recreation, often slighted in facility design, emphasis on service and flexibility.

TEST PROBLEM ALTERNATIVES continued

PROBLEM STATEMENTS	DESCRIPTION
I. This space should provide food dispensing and consumption facilities for one to twelve faculty, staff, or students as a part of a major classroom building. The primary use of this space will be the storage and dispensing of cold and hot snack foods, with related preparation and consumption of food. Other related uses may include small group discussion and individual reading or studying.	Represents a "Campus Snack Bar", a typical function, usually minimally treated.
J. This space should provide recreational facilities for one to twenty students as a floor unit of a large dormitory complex. The major use of the space will be for a variety of light recreational activities including talking between floor residents or couples, recreational reading, studying, televiewing; some food may be provided or brought to the area; games (cards, chess, etc.) may also be used. Secondary uses may include periodic floor meetings, parties, mass televiewing (football, inaugurations).	Represents a "Dormitory Floor Lounge", an important campus function at this scale.
K. This space should provide recreation/study facilities for one to twelve graduate students, and periodically small groups of faculty, related to the departmental area. The primary space use will be for a variety of recreational activities, light reading of newspapers, books, magazines, eating-drinking coffee or brown bags, informal talking in small groups. Secondary uses may include informal small seminars, birthday parties, food vending.	Represents a "Departmental Lounge", an important amenity infrequently provided.
L. This space should provide food preparation and consumption facilities involving three to five staff and from four to thirty students, faculty, or staff as a part of a classroom building or dormitory. Primary space use will include a preparation area for fountain and short-order items, with provision for individuals and groups to consume food. Secondary uses may include small group discussion, game playing, parties, or films.	Represents a "Coffee Shop", a more specialized, technical alternative, with food processing on the premises.

APPENDIX B TEST STRATEGY DETAILS

These appendices describe the details involved in generating the design strategies to be used in the experiment, including the development and results of the National Survey of design methodologists, and the strategies developed from the Survey, with the experimental hypotheses derived from differences between strategies.

Appendix B-1 List of Design Strategies

This lists the major steps identified by various authors either as design strategies or as models of the design process. These strategies were assembled and organized by general type or application as a survey of existing opinion on design strategies and a source for the development of the National Survey questionnaire and the generation of the specific test strategies.

LIST OF DESIGN STRATEGIES

BASIC STEPS:

A. Archer
1. Preparation of a Product Performance Specification
2. Establishment of the Design Resources
3. Development of Design Solutions
4. Evaluation of Design

B. Christopherson
1. Conception
2. Realization
3. Communication

C. Jay
1. Survey
2. Plan
3. Implementation

D. Jones
1. Analysis
2. Synthesis
3. Evaluation

E. Roe
1. Identification of a Problem
2. Search for a Solution
3. Evaluation of Solutions
4. Selection of the Best Solution

F. Wallas (Whitfield)
1. Preparation
2. Incubation
3. Illumination
4. Verification

OPERATION TYPES:

A. Alger
1. Recognizing
2. Specifying
3. Proposing Solutions
4. Evaluating Alternatives
5. Deciding on a Solution
6. Implementing

B. Alger (industry)
1. Recognize
2. Define
3. Conceive
4. Apply
5. Evaluate
6. Communicate

C. Alger (university)
1. Analysis
2. Synthesis
3. Evaluation and Decision
4. Optimization
5. Revision
6. Implementation

D. Archer
1. Policy Formulation
2. Preliminary Research
3. Sketch Designs
4. Detailed Designs
5. Prototype Construction
6. Marketing Appraisal
7. Production Design
8. Production Planning
9. Tooling
10. Production and Sale

E. Falcon (Whitfield)
1. Preparation
2. Information
3. Evaluation
4. Creation
5. Selection
6. Implementation

F. Hykin
1. Recognition
2. Definition
3. Preparation
4. Analysis
5. Synthesis
6. Evaluation
7. Preparation

G. Murtha (processes)
1. Orientation
2. Translation
3. Generation
4. Development
5. Formulation
6. Evaluation

LIST OF DESIGN STRATEGIES continued

H. Murtha (protocal)

1. User Problem
2. Design Problem
3. Solution Concept
4. Solution Development
5. Solution Formulation
6. Solution Evaluation

I. Murtha (functions)

1. Definition
2. Data Generation
3. Computation
4. Design
5. Decision
6. Post-Design

PROBLEM-SOLVING:

A. Burnette

1. Problem Identification
2. Directive and Instructive Statements of Purpose
3. Collecting and Discriminating Data
4. Conceptualization, Organization, Relation and Grouping of Elements
5. Formal Mediating Representation of Problem or Solution
6. Experiencing, Recording Results of Carrying Out Plan

7. Retrospective Evaluation and Analysis

B. Dewey (Guilford)

1. Recognition of a Program
2. Analysis of the Problem
3. Suggestion of Possible Solutions
4. Testing of the Consequences
5. Judgement of the Selected Solution

C. Dewey (Whitfield)

1. Difficulty Felt
2. Difficulty Located and Defined
3. Possible Solutions Suggested
4. Consequences Considered
5. Solution Accepted

D. Gagne

1. Statement of the Problem
2. Refining the Problem by Distinguishing Essential Features
3. Searching for and Formulating Hypotheses
4. Verifying the Solution

E. Murtha (general model)

1. Initiating the Problem
2. Formulating the Problem
3. Developing the Information
4. Determining the Solution
5. Completing the Solution

F. Osborn (Whitfield)

1. Orientation, Pointing Up the Problem
2. Preparation, Gathering Pertinent Data
3. Analysis, Breaking Down Relevant Material
4. Hypothesis, Piling Up Alternatives
5. Incubation, Invite Illumination
6. Synthesis, Putting Pieces Together
7. Verification, Judging Ideas

G. Rossman (Whitfield)

1. Need or Difficulty Observed
2. Problem Formulated
3. Available Information Surveyed
4. Solutions Formulated
5. Solutions Critically Examined
6. New Ideas Formulated
7. New Ideas Tested

LIST OF DESIGN STRATEGIES continued

SYSTEM DESIGN:

A. Maas
1. Identifying Objectives
2. Translating Objectives Into Criteria
3. Using Criteria to Devise Plans
4. Optimization
5. Evaluation of Consequences

B. Mac Rae (Whitfield)
1. Problem Identification
2. Problem Research
3. Problem Definition
4. Ideation Phase
5. Judgment
6. Test
7. Formulate Plan
8. Coordinate
9. Action

C. Nadler (Ideal System)
1. Determine Function
2. Develop Ideal System
3. Gather Information
4. Suggest Alternatives
5. Select a Solution
6. Formulate the System
7. Review the System
8. Test the System
9. Install and System
10. Measure and Control Performance

D. Roe (pattern)
1. Organization of Initial Problem
2. Drawing Upon Physical Phenomena That Can Produce Solution
3. Establishment of Con-Straints Upon Perform-ance of Solution
4. Collection or Generation of Several Methods for Constructing Solution
5. Characterization of Social, Economic, Financial Factors
6. Establishment of Criter-ia for Selection of Solution Alternative
7. Optimization of Design

E. Roe (morphology)
1. Defect in Environment
2. Need Analysis
3. Definition of Design Problem
4. Development of Design Criteria
5. Development of Alter-native Solutions
6. Analysis of Feasibility
7. Optimization
8. Selection of Solution to be Used

9. Implementation and Communication
10. Rectified Defect in the Environment

F. Wilson
1. Establish Criteria
2. Create a Mathematical Model
3. Establish Component Characteristics
4. Test Components
5. Test Subsystems
6. Evaluate System From the Mathematical Model
7. Optimize and Redesign

ENGINEERING DESIGN:

A. Buhl
1. Establish a Problem Area
2. Determine Exactly the Nature of the Problem
3. Collect Pertinent Information
4. Break Down and Study Information
5. Assemble and Analyze Information into Various Configurations
6. Study the Merits of Each Possible Solution and Select
7. Sell the Chosen Solution

LIST OF DESIGN STRATEGIES continued

B. Dixon (design process)
1. Goal Recognition
2. Task Specification
3. Concept Formation
4. Engineering Analysis
5. Solution Specification
6. Production
7. Distribution, Sales, Servicing

C. Dixon (engineering analysis
1. Define the Problem
2. Development of a Plan
3. Model Formation
4. Computation
5. Checking
6. Evaluation
7. Optimization

D. Eder
1. Preliminary Analysis
2. Investigation
3. Synthesis
4. Development
5. Completion

E. Eder and Gosling
1. Specification of the Required Solution
2. Formation of System Models
3. Realization
4. Optimization
5. Layout

F. Pare
1. Problem Statement, Identification and Requirements
2. Design Specifications, Investigation, Research
3. Investigate and Evaluate Possible Solutions
4. Component Design, Interrelated Analysis
5. Checking the Design

G. Rogers
1. Reconnaisance, Salient Features
2. Strategic Objectives, Translation, Design Implications
3. Alternative Strategies, Sketch Diagrams
4. Alternative Tactics, Design Development
5. Implementation

H. Rosenstein (Whitfield)
1. Statement of Problem; Formulation of Needs
2. Information, Collection, Organization
3. Modeling, Parameters, Variables
4. Value System Formulation, Constraints, Criteria
5. Synthesis of Alternatives
6. Analysis and/or Test
7. Evaluation
8. Decision
9. Optimization
10. Communication
11. Implementation

I. Wilson
1. Statement of Needs and Objectives
2. Establish Feasibility
3. Preliminary Design
4. Development, Research, Information Gathering
5. Prototype Construction
6. Test and Evaluation
7. Final Design
8. Production and Construction
9. Operation and Maintenance

MACHINE DESIGN:

A. Doughtie
1. Statement of Purpose of Machine
2. Select Mechanisms for Desired Motion
3. Determine Energy and Forces
4. Select Material
5. Determine Size

LIST OF DESIGN STRATEGIES continued

6. Modify Members, Judgment and Manufacturing
7. Make Drawings

B. Freund
1. Apprehension of Task
2. Gathering Data
3. Synthesis of Scheme
4. Analysis of Members for Loads
5. Selection of Materials
6. Calculation of Dimensions
7. Drawings and Specifications for Members
8. Final Total Design

C. Maleev
1. Stating the Problem
2. Analyzing the Problem
3. Selecting the Mechanism, Material, Stresses
4. Preparing the Preliminary Design
5. Revising the Design
6. Making Final Drawings

D. Myatt
1. Initial Idea, Expression of Need
2. Screening the Idea
3. Breadboarding the Machine Concept
4. Prepare the Prototype Model
5. Production Model
6. Sales and Distribution

ENVIRONMENTAL DESIGN:

A. Archer (1965)
1. Programming
2. Data Collection
3. Analysis
4. Synthesis
5. Development
6. Validation
7. Communication

B. Archer (1969)
1. Given Requirements
2. Given Resources
3. Identify Performance Laws
4. Identify System Laws
5. Identify Resource Laws
6. Establish Context
7. Postulate Decisions
8. Determine Performance
9. Determine Merits

C. Asimow
1. Feasibility Study
2. Preliminary Design
3. Detailed Design
4. Planning for Production
5. Planning for Distribution
6. Planning for Consumption
7. Planning for Retirement

D. Burnette
1. Client Contact
2. Program Elements
3. Preliminary Design
4. Presentation
5. Working Drawings
6. Construction Supervision
7. Follow Through

E. Geddes and Spring (AIA)
1. Identification, Goals, Needs, Limitations
2. Formulation, Alternatives strategies, Procedures for Form, Content, Process
3. Prediction, Consequences of Alternatives, intuitive Analysis
4. Selection, Find Alternative Best Meets Performance Requirements
5. Management, Implement Alternative Selected
6. Evaluation, Examine Consequences of Action Taken, Feedback Corrections

F. Royal Institute of British Architects
1. Inception
2. Feasibility
3. Outline Proposals
4. Scheme Design
5. Detail Design

LIST OF DESIGN STRATEGIES continued

6. Production Information
7. Bills of Quantities
8. Tender Action
9. Project Planning
10. Operation on Site
11. Completion
12. Feedback

PLANNING:

A. Hallett
1. Clarify the Field of Action
2. Anticipate Unchangeable Elements in the Field
3. Analyze Controllable Elements With Respect to Alternative Consequences or Ends in View
4. Present Actors with the Options Among Which a Choice will be Made and Action Taken

B. Jay
1. Survey, Present and Proposed System Characteristics
2. Formulation of the Plan, Policies, Physical Design
3. Implementation, Control of Development

C. Draper (Lewis)
1. Careful Surveys and Inventories of Resources
2. Analysis of the Facts
3. Appraisal of the Situation
4. Considered Opinion

D. Maas
1. Identifying the Objectives
2. Translating Objectives into Criteria
3. Using Criteria to Devise Plans
4. Optimization
5. Evaluating the Consequences

E. Reedy (Maas)
1. Collection of Needed Information
2. Prepare Tentative Plan, Based Upon Analysis of Information
3. Search for Optimal Plan By Modification and Incremental Analysis

F. Schaffer
1. Research
2. Formulation of Objectives
3. Strategic Planning
4. Operational Planning

Appendix B-2 National Survey Step Alternatives

This lists the "step" alternatives which were provided on the National Survey questionnaire, accompanied by brief descriptive material explaining the basis for their inclusion. The steps are listed here under general functional categories to aid in understanding their meaning and application, although the categories were not used in the questionnaire, and the order of presentation was varied to some degree.

NATIONAL SURVEY STEP ALTERNATIVES

STEP STATEMENTS	DESCRIPTION
A. Definition Steps	Usually used to initiate a design strategy, provide basis for establishing the nature or requirements of the problem; variations occur in degree of specificity and types of information involved.
1. Definition of the Problem	Considered as one of the basic steps, a general concept of definition which must be reinterpreted in the designer's own terms.
2. Examination of the Problem	Similar to the above step, open to broader interpretation.
3. Determination of Needs	Involves more specific information, usually "client" needs, still very open-ended.
4. Determination of Objectives	A common approach, identifying major goals, objectives or purposes as overall problem contraints, usually provided by client.
5. Determination of Performance Requirements	More operational, definition of particular requirements which the solution must satisfy may be provided by client or through designer's examination of the problem.
6. Determination of Solution Resources	Used either for initial definition or later in the design process to establish boundries on the search for a solution.
7. Determination of External Constraints	Also used alternately at different points in the design process, to establish external factors such as legal or physical laws, uncontrollable variables, etc.

NATIONAL SURVEY STEP ALTERNATIVES continued

STEP STATEMENTS	DESCRIPTION
B. Planning Steps	Less common steps, introduced at various points in the process, developing approach for subsequent activities.
8. Planning Problem-Solving Approach	Usually used after initial definition to formulate specific plan of attack for solving problem.
9. Planning Data Gathering	Pre-specifying or delimiting the type of information search needed.
C. Information and Organization Steps	Alternative approaches and degrees of rigor used in generating design information and establishing relationships between variables.
10. Gathering Data	Another basic step, large-scale information collection after the initial definition.
11. Organization of Data	Represents different interpretations and techniques for structuring information that has been gathered.
12. Development of Models	A more specific and operational approach to data organization implying a mathematical or other systematic form of organization and representation.
13. Determination of Relationships • Between Requirements	A specific organizational step stressing relationships and interactions between problem requirements.
14. Identification of Subproblems	An organization or breakdown of problem aspects into specific areas representing conflicts, difficulties, or subdivisions.

NATIONAL SURVEY STEP ALTERNATIVES continued

STEP STATEMENTS	DESCRIPTION
15. Determination of Relationships Between Solution Elements	Usually used late in the design process, makes explicit, usually intuitive, activity establishing relationships among solution elements.
D. Solution Generation Steps	Different approaches and levels of solution generation, indicates position in problem-solving sequence at which a given level of solution is to be considered.
16. Incubation	Frequently found in "creativity" literature, a period of subconscious information processing or problem-solving activity.
17. Illumination	A parallel, subsequent creativity step, a more or less spontaneous generation of the problem solution.
18. Generation of Conceptual Solutions	Used either early or late in the process, formulation of a tentative, overall version of solution as a basis for further development.
19. Generation of Subsystem Solutions	Used where problem is solved by parts of the whole, an intermediate step before recombination in the overall formal solution.
20. Generation of Formal Solutions	Another basic step, generation of the overall solution either before or after detailed development of the solution.
E. Solution Development Steps	An expansion, usually continuation, of the basic solution generation, representing different approaches to similar operations.

NATIONAL SURVEY STEP ALTERNATIVES continued

STEP STATEMENTS	DESCRIPTION
21. Development of Solutions	A rather general approach, an overall consideration of solution variables and refinement of the solution configuration.
22. Modification of Solution Elements	A more specific adjustment of fit for previously established solution elements.
23. Detailing of Solutions	Usually the final specification of individual details within an overall solution system.
24. Refinement of Final Solution	Relatively minor modification of specifications tightening up a previously completed solution.
F. Evaluation Steps	Judgment steps which may occur at different points in the process, representing different approaches or levels of evaluation.
25. Establishment of Feasibility	May be used at different points in the process; establishing the feasibility or possibility of finding a workable solution to the problem.
26. Screening of Conceptual Solutions	Usually paired with "generation of conceptual solutions", a comparative judgment of the suitability of different conceptual alternatives.
27. Optimization of Solution	A specific technique used to systematically compare and balance different solution variables to establish the best combination of factors.

NATIONAL SURVEY STEP ALTERNATIVES continued

STEP STATEMENTS	DESCRIPTION
28. Determination of Evaluation Method	May be used at different points in the process, a specific consideration of the means to be employed in evaluating the solution or solutions.
29. Review of Solution Consequences	A specific evaluation technique, projecting the solution into the real world and attempting to predict the effect or consequences of use.
30. Evaluation of Solution	Another basic step, represents the overall concept of solution evaluation, may or may not involve or supplement specific evaluation techniques.
31. Selection of a Final Solution	Narrows down the general evaluation process to a relatively simple matter of selecting or distinguishing between solution alternatives.
G. Continuation Step	A final step included to indicate the continuation or extension of the design process into areas such as fabrication, implementation, operation of the solution in the real world, not necessarily considered as part of the formal design process.
32. Implementation and Follow-Through	See above.

Appendix B-3 National Survey Assumption Alternatives

This lists the "assumption" statements which were presented on the national survey, with descriptive information indicating the basis for inclusion and identifying philosophical differences represented by different statements. Again, the groupings and headings shown are provided especially for this listing to aid in understanding.

NATIONAL SURVEY ASSUMPTION ALTERNATIVES

ASSUMPTION STATEMENTS	DESCRIPTION
A. Strategy Function	Major differences of opinion about how strategies should be presented and used by designers.
1. Steps in the strategy should be identified and defined only as a general framework for problem-solving, stressing the need for individual intuition and creativity.	The most conservative view, regarding the strategy essentially as a stimulus for inherant creativity.
2. The definition of steps in a strategy should be kept as general and open-ended as possible to allow individual designers to make their own interpretations and adaptations to the specific problem.	A more rational approach, regarding the strategy as a useful tool, but still maintaining the concept of "freedom" for the designer.
3. The identification of steps in a strategy should include sufficient detail to describe what needs to be done at each point in the problem-solving process in such a way that systematic decision-making and information processing can be applied to the given specific problem.	Stresses the utility of the strategy is a means of providing a systematic guide for problem-solving.
B. Design Process Assumptions	Various assumptions about the nature of the design process, and the ways in which designers solve problems.
4. The design process should be essentially self-conscious in the sense that the designer should specifically plan out: the objectives of problem-solving, the plan of attack for reaching a	An acceptance of the designer's ability to plan his own work, and the desirability of planning within the design process.

NATIONAL SURVEY ASSUMPTION ALTERNATIVES continued

ASSUMPTION STATEMENTS	DESCRIPTION
solution, the program for obtaining information, the methods to be used in evaluation, etc.	
5. While the sequence of steps shown in the strategy should indicate the typical order of consideration, the need for feedback and feedforward between steps should be clearly indicated.	A specific functional view of the design process, indicating the need for flexibility in revision and anticipation.
6. The entire problem-solving process should be considered as a continuum and strategies should indicate the transformations of ideas and information from the initial problem statement to the final solution.	A view found in the theoretical literature, almost wholistic approach to the design process.
7. The information used in the design process should essentially be developed in four phases: the user's needs or objectives, the user requirements redefined in terms of design questions, the design questions answered in terms of solution or performance requirements, and the performance requirements solved in terms of solution specifications.	A more specific, constrained approach, suggested by the work of some practitioners.
8. It should be understood that analysis and synthesis are not distinct steps in the problem-solving sequence, but rather they are used throughout the process in developing problem definitions, solution concepts, solution details, etc.	A view in contradiction to an approach commonly taken in the early design strategies.

NATIONAL SURVEY ASSUMPTION ALTERNATIVES continued

ASSUMPTION STATEMENTS	DESCRIPTION
C. Specific Operational Approaches	Different approaches taken with regard to key steps or operations in the design process.
9. The problem-solving process should begin with as complete and detailed a specification of the problem as possible, identifying all of the client's needs, objectives, and performance requirements.	Supports the concept of using extensive detail early in the design process.
10. The initial description of the problem should include only the minimum essential limitations or constraints, with the more detailed specifications introduced in the context of a specific solution concept or approach.	A contrasting viewpoint to the above.
11. The definition of the problem should be as "operational" as possible describing the literal function or purpose of the proposed environmental system, rather than simply restating the client's goals or objectives.	A recently developed approach related to the systematic design philosophy.
12. The search for a solution should begin with the generation of a set of "ideal" or best possible solutions which would satisfy a set of minimum limitations under the most favorable conditions, and which could then be developed in terms of available resources and more specific limitations.	Another aspect of the operational or systematic approach suggested by some practitioners.

NATIONAL SURVEY ASSUMPTION ALTERNATIVES continued

ASSUMPTION STATEMENTS	DESCRIPTION
13. As early in the problem-solving process as possible an attempt should be made to gather all of the available information related to the problem and its solution, as a basis for problem analysis and solution generation.	A viewpoint which has traditionally received wide acceptance in the creativity and design methods literature.
14. The gathering of information used in problem-solving should be highly selective, including only relevant information which is introduced throughout the process as it is actually needed.	A contrasting viewpoint, to the above, introduced as part of the systematic approach.
15. Wherever possible alternative forms should be developed for solution elements such as conceptual solutions, formal solutions, solution details, etc., in order to facilitate the comparison and combination of elements in the final solution.	An assumption included in the systematic approach as a means of maintaining flexibility in the design process.
16. Evaluation of solutions should be based directly on the limitations and performance requirements developed from the original problem statement.	Another systematic aspect, applying the definition directly in evaluation as a means of insuring solution suitability.
D. Overall Problem-Solving Approaches	Additional assumptions related to treatment of problems and development of solution.

NATIONAL SURVEY ASSUMPTION ALTERNATIVES continued

ASSUMPTION STATEMENTS	DESCRIPTION
17. Any design problem can be considered in a "system" context, indicating inputs, outputs, external environments etc., and stressing the functional interaction between components and subsystems.	The concept of systems has been powerfully applied in other fields and has recently been considered as the core of the systematic approach in design methods.
18. Almost any problem can and should be subdivided into components and subsystems which can be solved separately and then recombined to form the final solution.	Considered by some to be a logical extension of the system approach; as contrasted with treating the problem and its solution as a whole.
19. It should be acknowledged that almost all solutions are essentially modifications or extensions of existing environmental systems with the differences due primarily to the new technology or other resources or minor shifts in the pattern of user needs.	An explicit statement of a view which seems to underlie many traditional design strategies, as contrasted with the concept of deriving unique solutions in response to specific needs.

Appendix B-4 National Survey Results

This lists the principal observations made from an examination of Tables 3-3 and 3-4, the step and assumption results from the national survey. These observations describe important similarities and contrasts in current opinion, which were used as a basis for generating test strategies representing different spectrums of opinion.

NATIONAL SURVEY STEP RESULTS

1) 11 out of the 13 respondents made entries in this section.

2) Every step was cited at least once.

3) The smallest number of steps cited by a respondent was 10.

4) The largest number of steps selected by a respondent was 30.

5) Three respondents grouped a number of steps on the questionnaire into larger steps or stages.

6) The smallest number of steps or stages identified after regrouping was 6.

7) The average number of steps in a sequence was 16.

8) The steps cited least often were "incubation" and "illumination".

9) Other steps cited infrequently were "relating solution elements", "planning problem-solving", and "optimizing".

10) Low ranking steps with citations by less than ½ the respondents were "identifying subproblems", "modifying solution elements" and "screening conceptual solutions".

11) The highest ranking steps with citation by 3/4 or more respondents were "defining problem", "determining problem requirements", "determining objectives", "selecting solution", and "implementing solution".

12) The various problem definition alternatives were predictably grouped at the beginning of the sequence by all respondents.

13) In two instances, however, determination of "solution resources" and "external constraints" were located after "data gathering".

14) Most respondents used all or almost all of the definition alternatives, however, two respondents used essentially a two-step sequence of "defining the problem" and "determining performance requirements".

15) Two respondents used "determining performance requirements" as a later step following the initial problem definition.

16) Most respondents used "defining" or "examining the problem" as a first step, however, three respondents used "defining the problem" as a resolution or synthesis step following the specific definition steps.

17) "Planning the P-S approach" while used infrequently, was twice grouped with "planning data gathering" and was used as an intermediate step before

"determining performance requirements" and "generating conceptual solutions".

18. "Planning data gathering" was almost always linked directly to the step "gathering data" with one exception where it was used as the first step in the problem-solving sequence.

19. The "gathering data" step almost invariably followed the problem definition steps, although in two cases it was preceeded by some solution development steps.

20. "Gathering data" was almost always linked with "organizing data" and in four cases formed a 3-step sequence with "developing models".

21. There were no clear patterns of sequence for "determining relationships" between "requirements" or "solution elements" or for "identifying subproblems" either of which could occur quite early or very late in the sequence.

22. "Conceptual solutions" was linked to different types of information organization in 5 cases and in 2 cases was used as an initial definition step.

23. "Subsystem" and "formal solution" Generation followed "data gathering" and "organization" in almost all cases.

24. "Subsystem solutions" were grouped with "formal solutions" in 3 cases, and in 2 of these they immediately followed "conceptual solutions".

25. Solution development steps were almost always grouped with solution generation steps, usually following the initial generation step.

26. "Solution development" and "modification" were linked more or less directly in 4 cases, and always proceeded or occurred at the same level as "solution details".

27. "Solution detailing" occurred as one of the last steps in the sequence in 3 cases.

28. "Solution refinement was treated similarly to the above, occurring as one ofthe last steps in all cases where it was cited.

29. The evaluation steps tended to be located toward the end of the sequence, although there was considerable variability.

NATIONAL SURVEY STEP RESULTS continued	NATIONAL SURVEY ASSUMPTION RESULTS
30. "Determining feasibility" was treated as a part of solution development in 6 cases, however, in 2 instances it was used quite early in connection with problem definition. 31. "Optimization" and "review of consequences" were usually considered as a part of the final evaluation process, although either or both of them were used after "evaluation" or "selection" in 4 cases. 32. "Screening conceptual solutions" was usually linked with "generating conceptual solutions", although in 2 instances it was considered as a separate operation. 33. "Development of the evaluation method" was linked directly to "evaluation" in 2 cases, but in 4 other instances it preceeded the generation of solutions. 34. "Evaluation" and "selection" of the final solution occurred together in all but 1 instance, usually grouped with "refining" and "implementing" the solution. 35. "Implementing the solution" occurred as the final step in all but 1 of the cases in which it was used.	1. All 13 respondents completed at least a part of this section. 2. Each assumption was cited at least twice. 3. The average number of assumptions cited by a respondent was 8. 4. The assumptions cited least often referred to "4-phases", "ideal solutions" and "modifying existing solutions". 5. Other assumptions infrequently cited were "minimum limitations" and "evaluation based on problem requirements". 6. The highest ranking assumptions were those related to "refuting analysis and synthesis", "the systems approach", "open-ended definitions", "continuum of transformations", and "alternative solution approaches". 7. The Strategy Function assumptions were frequently interrelated, 2 respondents cited all three, and 4 others cited two of the three. 8. The function assumption related to "framework for intuition" was always combined with one of the other assumptions, while the "systematic function" was cited alone in 3 cases.

9. While there were variations in the frequency of citation, there was a tendency to accept most of the Design Process assumptions; of the five assumptions listed, 3 respondents cited four of the assumptions, and 3 other respondents cited three of the five assumptions.

10. There was a definite absense of pattern in citing the Design Process assumptions, no 2 respondents showed a consistent pattern of citations.

11. In the Specific Operational assumptions, respondents established patterns of relationship in which 2 or more respondents cited the same pairs of assumptions, as follows:

    a. "detailed definitions" was linked with "minimum limitations", "operational definitions", "selecting all information" and "evaluation based on problem requirements".

    b. "minimum limitations" was linked with "operational definitions" and "selecting all information".

    c. "operational definitions" was linked with "selecting all information", "selecting relevant information", and "evaluation based on problem requirements".

    d. "ideal solutions" was linked with "selecting relevant information".

    e. both "selecting all information" and "selecting relevant information" were linked with "evaluation based on problem requirements".

    f. all assumptions in this group were linked with "solution alternatives".

12. By contrast, "selecting all information" and "selecting relevant information" were cited mutually exclusively in all 10 instances.

13. There were no clear patterns in Overall Problem-Solving Approaches, however, it was interesting to note a relatively low level of correspondence, 3 out of 11 instances citing both "systems" and "subsystems" assumptions.

Appendix B-5 Test Strategy Development

This lists the specific steps and step definitions which were provided to subjects in the orientation materials for use in the experiment, accompanied by descriptive information indicating the specific differences which were built into the different test strategies.

TEST STRATEGY DEVELOPMENT

STRATEGY STEP	DESCRIPTION
A. Out-Line Strategy	An annotated description of the five principle divisions in the design process as confirmed by the National Survey. Definitions are very general, but a fair amount of detail was included to make the strategy convincing to the subjects.
1. Defining the Problem Develop a general picture of the problem area or environment which you have been asked to design. As much information as possible should be assembled to describe the nature of the problem, the various aspects which must be considered, and to clarify what needs to be done in solving the problem.	Key concepts are "general" and "as much information as possible", a variation on the assumption that definitions should be as detailed as possible.
2. Gathering Data Collect as much information as possible about problem details and possible means of solution in order to develop a pool of information which can serve to stimulate creative thinking and provide the basis for solution development.	Represents the assumption that "all possible information" should be gathered, reflects the intuitive approach to information use and organization.
3. Developing Preliminary Solution Sketch out a preliminary solution indicating your general approach, identifying major physical elements or components and basic configurations or arrangements of elements, this should be quite general at first with the details added later.	Continues the intuitive approach in which the solution is generated directly from the raw data, the sketch solution is deliberately vague and suggests a number of possible interpretations including one variation of the "conceptual solution".

TEST STRATEGY DEVELOPMENT continued	
STRATEGY STEP	DESCRIPTION
4. Detailing the Solution Refine the solution idea, adding greater detail and working with the specifications for individual components, assemble all elements into an overall solution or set of components and complete the solution details.	The refining or detailing step is widely accepted although it is only generally described for this strategy, reference is also made indirectly to "subsystems" to insure credibility of the strategy.
5. Evaluating Solution Check over the final solution and be sure that no errors have been made in the solution specification and verify that the solution does in fact solve the problem as given, check solution details for completeness.	More intuitive approaches tend to minimize the evaluation step, with the emphasis on checking over the work or verifying the solution in a general way.
B. Detailed Strategy	A highly typical strategy in terms of number and type of steps and generality of definition, following most of the more popular steps and assumptions from the National Survey
1. Develop a working definition or orientation to the problem area or environment which you have been asked to design. Refer to the people who will build and use the environment and determine their needs and problems and the limits they place on the solution. This should provide a set of conditions which any solution must satisfy. This need not be too detailed, but should cover all important areas.	Reflects the survey steps for "determining user needs, objectives, and performance requirements", as well as presenting a compromise on the "detailed definition" assumption, in general reflects a typical focus on the "user".

TEST STRATEGY DEVELOPMENT continued

STRATEGY STEP	DESCRIPTION
2. Determining Solution Constraints Redefine the problem in operational terms by determining the impact of the requirements on variables in the physical environment and by determining the limitations related to solution resources and external constraints. This should define the problem space or area of decision in developing the solution.	Completes the list of major definition steps as provided in the survey, rephrasing "determination of performance requirements" and including "solution resources" and "external constraints" also provides a variation on the "operational definition" assumption.
3. Gathering Data Specific data or information related to the problem should be gathered based on questions arising from the problem definition. This should include only relevant information which is actually needed and the search area or limits should be determined before actually gathering the data.	Maintains the sequence of operations as identified from the survey, includes the step of "planning data gathering" and the assumption on "relevant information".
4. Organizing Data The data which has been gathered should be organized for use in the problem-solving process, specifying groupings of data items, identifying relationships, and displaying the information for convenient review, understanding, and application.	Represents the steps for "organizing information" and "determining the relationships between requirements", the "developing models" step was omitted due to time constraints and possible confusion.
5. Developing Conceptual Solutions The area of work in solution development should be identified in a first pass which provides a general picture of the solution. An overall view of the solution	Another variation on the "conceptual solution" step, described as a tentative solution approach, somewhat more rigorous than the "sketch" concept.

TEST STRATEGY DEVELOPMENT continued	
STRATEGY STEP	DESCRIPTION
should be determined in terms of assumptions and concepts related to major physical elements or components and their configuration or arrangement. This need not be too specific but should provide the basis for further development.	
6. Developing Subsystem Solutions	
The development work on the solution should be simplified by subdividing the solution as a whole into subsystems or specific components or groups of components which can be more easily handled. Subsystem solutions should work out the details of meeting problem requirements in the physical solution.	Continues the sequence identified from the Survey; reinforces the essentially mechanical subsystem breakdown as given in the assumptions.
7. Developing Overall Solution	
Reassemble the subsystem solutions into an overall solution based on interactions and relationships between subsystems, resolving conflicts, and combining the parts into a coherant whole. Some details may remain to be developed but the solution should be considered as a whole in subsequent treatments.	Combines the "generation" and "development steps for the "formal solution", implies the "relation of solution elements".
8. Detailing Overall Solution	
Complete the solution by making additional refinements to insure that the solution is working together as a whole	Combines solution "detailing" and "modification", the popular "solution alternatives" assumption is used in the following strategy.

TEST STRATEGY DEVELOPMENT contined

STRATEGY STEP	DESCRIPTION
and that all details and specifications are accounted for. Some modifications may be made within the subsystems and additional elements may be added as required.	
9. Evaluating Solution Evaluate the solution which has been developed to insure that it meets the problem requirements, specific measures should be established and the evaluation should be systematic to insure that all aspects of the problem and solution have been considered.	Combines "planning the evaluation method" and "evaluating the solution", a sequence identified in the survey, also includes a version of "evaluation based on requirements".
10. Revising Solution Review the solution and make any additional refinements suggested by the evaluation. Check over the solution for completeness and take a final look at all aspects to insure that the solution is presented as you have planned.	A general version of "refining the solution" and includes reference to "checking" but as a final backup to the evaluation operation.
C. Systematic Strategy	An attempt by the experimenter to develop a highly useful strategy based on the most effective and systematic elements identified in the survey and the most current design literature.
1. Identifying Design Task Provide a general orientation to the problem by developing a simple statement describing the problem area or environmental system which you have been asked to design. Qualify this statement	A step not included on the questionnaire, but included in an attempt to more effectively initiate problem-solving with an overview taken before detailed work begins.

TEST STRATEGY DEVELOPMENT continued

STRATEGY STEP	DESCRIPTION
by identifying the purpose which you as a designer have in solving this problem.	
2. Determining Operational Definition Make the problem more explicit by developing a statement which describes the purpose or function of the proposed environmental system. This statement should indicate what the environment must do in order to meet the user needs and objectives, and should indicate the scale and emphasis of considerations in the design process.	A further refinement of the initiation process focussing on a specific system and its "function", particularly considering the system scale, and again using an overview concept before specific details.
3. Determining Minimum Limitations Specify the framework for developing a solution system which will accomplish this function by determining a set of limitations or conditions which limit the solution. These may include aspects of user requirements, available resources, or external constraints, but only those limitations which are absolutely essential should be included. The number of limitations should be kept to a minimum in order to permit an initial broad consideration of solution alternatives.	This applies the "operational definition" directly to the further development, and makes literal use of the "minimum limitations" assumption, it also covers most of the categories listed in definition steps on the survey.
4. Developing Solution Targets Start the solution development by attempting to identify and describe the best possible approach to solution of the problem, within the given function and minimum limitations. A number of alternative solutions should be provided in	A particular application of the "conceptual solution" relatively early in the process, based on the "ideal solution" assumption, again applies function and limitations directly, and begins using "alternative solutions".

TEST STRATEGY DEVELOPMENT continued

STRATEGY STEP	DESCRIPTION
general terms indicating key concepts, assumptions, and characteristics. An effort should be made to identify the most ideal approach to use as a goal or target in the more detailed solution development which follows.	
5. Screening Solution Targets Review the set of solution targets which were developed, in order to determine the one or two solutions which should be used as a guide in further development. Solutions should be examined to determine their feasibility and workability as targets using the limitations and additional information as required. If necessary, refine the selected solutions to make them even better.	Specifically written as a separate step to encourage the generation of numerous targets, as well as reinforce the importance of the target concept, also introduces an evaluation step early in the process, both "screening conceptual solutions" and "determining feasibility" were cited in the survey.
6. Gathering Data Gather additional data or information which is needed in developing the solution target as a final solution system. This information should be based on questions suggested by the solution target, clarifying problems and relationships associated with the target. Only relevant information should be selected which has direct application in developing the solution target.	Again the solution target used directly as a basis for proceeding, with the target guiding "planning for data gathering" and providing criteria for "relevant information".

TEST STRATEGY DEVELOPMENT continued

STRATEGY STEP	DESCRIPTION
7. Processing Data Organize and evaluate the data which has been gathered in order to determine and make explicit the implications of the data in completing the solution. The organization should indicate functional groupings of the data with interactions and interrelationships both within and between different types of data. Where possible, chains of reasoning should be described showing how data has been developed and how it should be applied in the solution.	A more developed version of "organizing information", stressing the "continuum" or chain of reasoning, extending the direct application of previous material seen above in the series from "operational definition" to "target" to "data gathering", also includes a broader statement of "relationships" and another early "evaluation" step.
8. Identifying Subproblems Identify specific subproblems which must be treated in developing the solution based on the data which was gathered and the conflicts or relationships developed in the data. This may include a range of subproblems related to meeting specific requirements, clarifying relationships, or detailing solution elements or components. Subproblems may relate to groups of variables or components or may include consideration of aspects affecting the entire solution.	A variation on the "subsystem" approach, stressing funct onal divisions of the problem, rather than a physical breakdown of the solution system elements, the separate identification step before subproblem solution emphasizes the importance of subproblem considerations.
9. Developing Subproblem Solutions Resolve problems which have been identified by specifying subproblem solutions which indicate related decisions with regard to individual elements or	Begins adding details to the target system at the subproblem level, controlling the detail, and indicating a specific use for "alternative solutions".

TEST STRATEGY DEVELOPMENT continued

STRATEGY STEP	DESCRIPTION
components or arrangements or configurations of components. This should include as much detail as is necessary to clarify areas of uncertainty and provide information needed for the final solution. Where appropriate alternative solutions may be provided with final decisions deferred until the final solution system is assembled.	
10. Integrating Subproblem Solutions	
Determine the relationships between subproblem solutions in terms of the overall solution concept. Subproblem solutions should be examined to determine how they would fit together in the overall solution system. This may include considerations of compatability, conflict, grouping relationships and the interactions of components and groups of components. Alternative arrangements or groupings should be considered and their relative advantages or disadvantages should be described.	Another separate step is used to highlight the importance of integrating subproblem solutions and other solution elements as a logical extension of "relating solution elements".
11. Developing Solution System Alternatives	
Assemble the components as determined in the subproblem solutions into an overall solution configuration or configurations. A number of different combinations or alternative solution	A demonstration of the flexibility possible in developing system alternatives from the subproblem components.

TEST STRATEGY DEVELOPMENT continued

STRATEGY STEP	DESCRIPTION
systems may be developed from the information at hand in different approaches to reaching the solution target and satisfying the problem requirements. While a number of possible alternatives should be considered, all alternatives suggested should provide reasonable approaches to the solution.	
12. Detailing Solution Alternatives	
Refine the different solution alternatives by adding additional details and making needed adjustments or modifications such that each of the alternatives provides a relatively complete solution. Detailing should remain consistent with the problem requirements and the approach as outlined in the solution target.	Applies the "detailing" step common to all three strategies to the solution "alternatives", maintaining the reference back to the solution target.
13. Evaluating Solution Alternatives	
Compare the different alternative solution systems with the problem definition and limitations and with each other to determine the solution which is closest to the solution target and which best solves the problem. Specific measures of effectiveness should be used, relating the problem requirements and limitations to the proposed environmental system. Where appropriate the best features of a number of solution systems may be	Focuses the various elements as developed in the strategy, applying the "operational" definition "minimum limitations" and "solution target" in the evaluation process, and bases the evaluation on comparing and choosing the best solution aspects which have been determined, also implies rigor with the specific "measures of solution effectiveness".

TEST STRATEGY DEVELOPMENT continued

STRATEGY STEP	DESCRIPTION
comoined in determining the final solution approach.	
14. Optimizing Solution	
Review the alternative solution system which was selected in the evaluation process to determine areas where additional refinement is possible based on adjustment and optimization of variables with respect to the measures of effectiveness which were developed. This should consider the trade-offs and compromises which were made and should attempt to make the best possible balance between all variables in the final solution system.	An adaptation of more formal "optimization" techniques used as a means of systematizing the "refinement" process and encouraging the development of the best possible solution.
15. Refining Solution	
Look over the final solution and attempt to identify areas in which the solution can be improved and brought closer to the ideal (target) solution. At the same time check all aspects of the final solution and clean up any loose ends or areas of uncertainty. Assume that any solution can always stand improvement and go back over all of the decisions that have been made, probing for any weaknesses in the reasoning or options that have been overlooked.	A specific iterative step, providing for a comprehensive review of the work in problem-solving, again stressing the importance of finding the best solution.

Appendix B-6 Test Strategy Hypotheses

This lists the hypotheses as presented in the report, with accompanying descriptive information indicating how each hypotheses was generated based on the nature of the differences between the three test strategies, with an emphasis on the different degrees of effectiveness which were designed into the strategies as derived from the experimenter's assumptions about the nature of design strategies and the design process.

TEST STRATEGY HYPOTHESES

HYPOTHESES	DESCRIPTION
General Hypothesis: Different strategies will produce different effects on design problem-solving based on the nature of the strategies.	This is an operational assumption for this type of research, and represents an opinion by the researcher which this study is designed either to support or refute.
Hyp. 1: The 5-step strategy should generally be more awkward and inefficient, producing unsatisfactory solutions.	In attempting to develop strategies which would demonstrate clear-cut differences, this strategy was assumed to be the least effective, since it offered the least assistance to the subjects, and it is assumed that without assistance the subject's subjective, intuitive understanding would not be able to cope effectively or efficiently with the problem-solving task.
Hyp. 1-1: The 5-step strategy should require more time for solution.	It is assumed that for the least effective strategy a large amount of time would be spent on unorganized random activity, which would waste time in problem-solving.
Hyp. 1-2: The 5-step strategy should require greater effort getting started on problem-solving.	The experience of the experimenter suggests that the initial steps in problem-solving are most difficult without a structured approach or guidance indicating "a place to start".
Hyp. 1-3: The 5-step strategy should be highly redundant with information indiscriminately selected and used.	Without a structured search process, there is usually a great deal of information which could be considered in problem-solving, and there is a tendency to gather extensive and excessive data which is laboriously refined

TEST STRATEGY HYPOTHESES contined

HYPOTHESES	DESCRIPTION
	in attempting to establish information relevance and application in the final solution.
Hyp. 1-4: The 5-step strategy should show great improvement in efficiency over repeated test sessions.	It is assumed that over time, the subjects would develop their own design strategy or methodology in the absence of specific guidance, which would still be less effective than a systematically developed strategy, but would be an improvement over early, random activity.
Hyp. 1-5: The 5-step strategy should produce generally poor solutions, improving over time.	This is a corollary to the previous statement, since an inefficient process would be unlikely to produce a high quality solution, although there might be some improvement through experience.
Hyp. 2: The 10-step strategy should be relatively easy to apply, but should be generally conservative, and somewhat inefficient.	In establishing strategy differences, this strategy was assumed to represent a large number of current strategies which have a "face validity" in appearing to comprehensively cover and explain the design process, but which suffer from a lack of specificity and operationality. Subjects are apt to approach problem-solving "confidently", but without a clear understanding of what they are doing.
Hyp. 2-1: The 10-step strategy should facilitate the start of problem-solving with little hesitation.	As indicated above, this strategy appears to given clear directions for starting problem-solving, although in actuality there may be difficulty in developing a working detinition.

TEST STRATEGY HYPOTHESES continued

HYPOTHESES	DESCRIPTION
Hyp. 2-2: The 10-step strategy should display considerable redundancy and inefficiency, with a relatively great concentration on details.	While the strategy does provide a basis for problem and solution development, the generality of the directions and the lack of tests for information relevance, usually lead to a diffuse development process, with random searching and redundancy in information selection and application.
Hyp. 2-3: The 10-step strategy should rely on practical considerations rather than conceptual appraoches.	Since the strategy was developed for the most part from conventional problem-solving methods, there is an emphasis on "cranking out" a solution detail, by detail, as opposed to other approaches which emphasize getting the "big picture" first.
Hyp. 2-4: The 10-step strategy should show relatively slight but constant improvement in efficiency over three sessions.	Subjects confident of their strategy should not be highly motivated toward improving their working method; but the unresolved questions in the directions should lead to some improvement with experience.
Hyp. 2-5: The 10-step strategy should produce moderate, traditional solutions with little improvement over time.	It is assumed that subjects using a more conventional strategy would also have a more conservative approach to problem solutions; as indicated above, there should be little incentive to change the approach between problems.
Hyp. 3: The 15-step strategy should be overall the most efficient and effective.	As the theoretically "best" strategy, this should produce the best all-around behavior, generating highly effective solutions as directly and economically as possible.

TEST STRATEGY HYPOTHESES continued

HYPOTHESES	DESCRIPTION
Hyp. 3-1: The 15-step strategy should provide for a direct, effective definition of the problem.	A good strategy should not only lead the subject directly and naturally into the problem-solving process, but should lead to the development of an operational problem definition which could serve as a guide throughout the process.
Hyp. 3-2: The 15-step strategy should utilize information selectively, with an efficient problem development.	As has been indicated, information processing lies at the heart of the design process; with a good working definition and with guidance for determining information relevancy, subjects should work with a limited body of highly relevant information, applied directly to the problem development.
Hyp. 3-3: The 15-step strategy should concentrate on conceptual information developing broad solution implications.	One approach to minimizing information redundancy, is to first develop the solution on an overall conceptual basis, testing alternatives on this level, before considering the design details for the specific solution approach which was selected.
Hyp. 3-4: The 15-step strategy should be relatively efficient initially, with little change over time.	If the strategy works well at its initial application, there should be little need for major improvements, since the strategy provides more extensive guidance there is less undertainty to be filled-in by experience.
Hyp. 3-5: The 15-step strategy should produce consistently high-level solutions with an emphasis on thoroughness and innovation.	The measure of a strategy is ultimately the quality of solutions which it produces; although this can be greatly determined by the efficiency of the design process, with a good operational definition, consistently applied throughout the process, with a limited information selection permitting a clear view of

TEST STRATEGY HYPOTHESES continued

HYPOTHESES	DESCRIPTION
	the problem, with a whole system view of the problem and its solution, it should be possible to generate very high quality solutions; with an emphasis on conceptual thinking, the solutions should be imaginative and innovative; above all, with the incentive and motivation provided by a very effective, workable strategy the subjects should make a real effort to find the best solution possible for every problem.

APPENDIX C INFORMATION BANK DETAILS

These appendices describe the details involved in the generation and application of the information banks used in this experiment, including sources of information, specific information categories, and operations and recording dimensions associated with the use of the information items.

Appendix C-1 Information Bank Sources

This lists the major sources of information used in the information bank, describing the various types of sources and the use that was made of the types of information in the banks. For specific sources used, see the Information Bank Bibliography.

INFORMATION BANK SOURCES

SOURCE TYPES	APPLICATION
1. Conversations with Campus Architect, UW-Madison.	Background information for orientation to problems, university policy, user requirements.
2. Conversations and Brochures from Madison office, Canteen service, Inc.	Background information on vending services, types of machines and food used in snack areas, typical room layouts.
3. Campus building "design standards" developed by University Facilities Research Center, UW-Madison.	Guidelines on user requirements, typical office and conference room furniture and equipment, typical office and conference room layouts.
4. "Building Programs" for two typical classroom buildings, prepared by Dept. of Planning and Construction, UW-Madison.	More specific statements of user requirements, activities, university policy, and typical furniture and equipment used in offices and conference rooms.
5. Publications from the library of the Environmental Design Dept., collected under the auspices of the Clearinghouse on Educational Facilities, Educational Research Information Clearinghouse, U.S. Office of Education.	Background and reference materials on the design of classroom buildings, included additional design standards and guidelines; and alternative proposals for typical furniture and equipment not included on the UW-Madison listing.

INFORMATION BANK SOURCES continued

SOURCE TYPES	APPLICATION
6. Classroom materials from the School of Architecture UW-Milwaukee.	Design principles and considerations to which subjects had been exposed.
7. Papers written by the Experimenter on design standards for teaching assistant offices, and hospital day rooms.	Basic human factors data on design of office furniture and spaces, design of dining facilities.
8. Trade journals, books, and articles related to office, restaurant, and educational facility design.	Design considerations, problems, and solutions in specific problem areas as developed by design practioners, lists of solution elements.
9. Text books and articles related to general or environmental design.	General design principles and considerations, alternative design techniques and procedures, psychological aspects of design.
10. Handbooks on Architectural Standards and Human Engineering	Additional data on human factors and physiological requirements, alternative solution elements, graphic descriptions of solution elements.
11. General background and experience of experimenter.	Additional user requirements, objectives, site and policy considerations, design considerations, solution details, formulation of specific statements for problem definitions, solution concepts.

Appendix C-2 Information Bank Structure

This lists the specific information categories included in the information banks, following the outline as given in the report, and accompanied by descriptive information on the nature of the information within each category. Note that the main categories as listed in the results' sections each include the specific sub-categories of information as described below. In addition, the main categories "D" and "F" were not considered appropriate for use in data analysis, and are not treated in the results.

INFORMATION BANK STRUCTURE

INFORMATION TYPE	DESCRIPTION
DEFINITION INFORMATION	Information used in setting-up the problem and determining the nature of problem-solving, descriptors are used to indicate what the designer is doing, requirements provide specific problem information. Data on information use indicates how subjects approach the problem.
A. Problem Descriptors	Indicates alternative approaches that might be taken by the designer in dealing with problems of this type.
A-1 Designer's Purposes	Describe the designer's own orientation toward his work.
A-2 Problem Identifiers	Relatively simple statements, identifying the general problem area or "system" under consideration.
A-3 General Definitions	Statements describing the function or "purpose" of the proposed environmental system, what it is supposed to do.
B. Process Descriptors	Alternative techniques, heuristics, organizational principles that might be used by the designer in processing problem information, included to allow subjects to identify specific activities.
B-1 Design Techniques	Different specific tools, techniques, or methods, series of operations to be performed within the strategy.
B-3 Relationship Types	Describing different ways of "grouping" information based on type of relationship or interaction.
B-4 Relationship Diagraming	Alternative "graphic" symbols which could be rendered in chalk to indicate techniques being used.
B-5 Data Categories	Indicates "types of information", categories which could be used to "label" different information groupings.
C. Overall Requirements	Statements about problem requirements as might be given by a hypothetical "client" or developed upon examination of the problem situation.

INFORMATION BANK STRUCTURE continued

INFORMATION TYPE	DESCRIPTION
C-1 Objectives	Indicating what is to be accomplished by the environmental design, in general terms.
C-2 User Requirements	Indicating how the inhabitants will use the environment, lists specific user purposes and major activities.
C-3 User Characteristics	Attitudes or personal needs of users which may affect design decisions in the environment.
D. Information Requirements.	Used only on the first problem, provides more specific user requirements in terms of information use within the environmental system.
D-1 Incoming Information	Types of information entering the system, which must be processed in some way.
D-2 Outgoing Information	Types of information leaving the system, which must be prepared or processed in some way by the user.
D-3 Information Processes	Different processes or procedures used in handling the information within the system.
E. General Requirements	Describes additional factors not directly related to user requirements, in this case the requirements were left open-ended with minimum constraint on the problem.
E-1 Administrative Policy	Conditions that might be imposed by groups "sponsoring" the construction of the environmental system.
E-2 Technical Limitations	Limitations on solutions due to available technology or other production-related factors.
E-4 Building Site	Limitations due to larger environmental systems within which the problem environment is located.
E-5 Natural Site	Limitations based on geography or characteristics of the area surrounding the proposed environment.

INFORMATION BANK STRUCTURE continued

INFORMATION TYPE	DESCRIPTION
DEVELOPMENT INFORMATION	Information which might be used in further describing or developing details of the design problem and its solution. Information use data should indicate the scope and direction of development, and the designer's general approach to information.
F. User Types	A list of possible users of the environment by type or title, available for combination with other items in describing specific requirements or activities, not treated separately in data analysis.
G. Action Types	A list of possible activities which might be performed by users in conducting more general activities as specified in the user requirements.
H. Design Considerations	Sets of items listing possible considerations or criteria used to establish problem limitations or requirements, usually in "adjective" form to be used with other specific requirement, activity, or solution element items.
H-1 Behavioral Factors	Considerations in man-environmental relationships as related to attitudes and psychological well-being.
H-3 Activity Factors	Considerations related to the design of environments or environmental components to accommodate specific user activities.
H-5 Design Factors	General considerations related to the design of a structure or configuration for the environment.
H-7 Illumination Factors	Specific considerations in the design of lighting or illumination for the environmental area.

INFORMATION BANK STRUCTURE continued

INFORMATION TYPE	DESCRIPTION
J. Research Information	Basic man-environment relationships identified to some degree by formal research to be used as design criteria in determining specifications for solution elements or components.
J-1 Ergonomic Factors	Physical dimensions and other limitations related to the human-user interacting with different environmental elements.
J-7 Psychological Factors	Basic psychological responses to different environmental elements or configurations.
K. General Information	Background information usually available to designers based on a survey of technical literature in the three problem areas, applicable for additional criteria or insights in solution development.
K-1 Standard Elements	Lists by name different solution elements, usually furniture or equipment, typically provided in environments similar to the test problem.
K-4 Typical Problems	Describes conflicts, difficulties, special design considerations identified by designers working in similar areas.
K-5 Typical Solutions	Specific solution elements or combinations of elements developed by designers solving similar problems.
K-7 Typical Layouts	Drawings of floor plans showing environmental configurations typically provided for situations of this type.
SOLUTION DESCRIPTION INFORMATION	Information of a general nature provided in contrast to the listing of specific solution elements in the following section, includes both overview statements on solution approaches, and solution modifers used to provide detail to specific elements. Data on information use indicates the degree to which subjects went beyond the basic elements in developing and specifying the solution (type category codes are presented out of the "alphabetic" sequence provided to subjects, in order to facilitate description and discussion).

INFORMATION BANK STRUCTURE continued

INFORMATION TYPE	DESCRIPTION
L. General Element Classes	Lists of different types of solution element by "generic" name or title, provided for use in outline or sketch solutions, and for the development of general requirement statements.
L-1 Material Types	Smaller items such as paper, pencil, food, etc. used with storage or work space.
L-2 Equipment Types	Equipment used as tools or communication devices in connection with different activities.
L-4 Furniture Types	Seating, Work surfaces, Storage, etc.
L-5 Space Types	Storage, Circulation Space, etc.
L-7 Enclosure Types	Walls, Ceiling, Doors, etc.
L-8 Furnishing Types	Equipment Surfaces, Wall Surfaces etc.
L-9 Arrangement Types	Built-In, Wall-Mounted etc.
Z. Solution Concepts	Sets of design "assumptions" describing alternative approaches or orientations toward the problem solution, used for conceptual or sketch solutions to indicate likely directions for further development.
Z-1 Functional Area Concepts	Identifies different room areas by major activity or function.
Z-4 Style Concepts	Overall "style" or theme for furniture, decor, etc.
Z-5 Equipment Concepts	General type or degree of dependence on mechanical aids.
Z-6 Lighting Concepts	General type or function of room lighting.
Z-7 Space Concepts	Type or amount of room space to be provided.
Z-8 Enclosure Concepts	Type or degree of enclosure or room space.
Z-9 Furnishing Concepts	Theme or atmosphere to be established by furnishings.

INFORMATION BANK STRUCTURE continued

INFORMATION TYPE	DESCRIPTION
Z-A Arrangement Concepts	Alternative grouping approaches for furniture and equipment.
Z-B Expression Concepts	Overall impression or character of the environmental system.
<u>W. Graphic Element Descriptions</u>	Sets of drawings illustrating a selected sample of solution elements, provided to supply additional detail and allow subjects to better visualize solution alternatives.
W-1 Body Support Configurations	Chairs, couches, etc.
W-4 Work Surface and Storage Configurations	Desks, work-tables, cupboards, etc.
W-6 Window Configurations	Standard, bay, clerestory windows, etc.
W-7 Door Configurations	Single, double, dutch doors, etc.
W-8 Floor Plan Configurations	Square, rectangular, trapezoidal with different proportions, for use in solution visualization, and identification of space coordinate systems.
X-Y. Element Specifications	Sets of properties to be included in details or specifications of solution elements to increase precision or comprehensiveness of description.
X-1 Natural Materials	Construction materials such as wood, rattan, stone.
X-4 Artificial Materials	Construction materials such as steel, plastic, glass.
X-6 Surface Treatment	Rough, smooth, textured, etc.
Y-1 Color, Hue	Red, Yellow, Green, etc.
Y-4 Color, Quality	Bright, Muted, Dark, etc.
SOLUTION ELEMENTS INFORMATION	Lists more than 300 separate items that might be included as solution elements in the final solution. Data on information use should indicate the scope or degree of complexity in solution development.

M-N. Material Elements	Different materials to be accommodated in the solution environment system.
M-1 Major Materials	Most immediately involved in user activities.
N-1 General Materials	Secondary or support materials, less important.
O-Q. Furniture Elements	Different types of furniture to be included in the solution.
O-1 Body Support	Different types of seating, chairs, couches, beds, etc.
P-1 Work Surfaces	Desks, tables, counters, etc.
Q-1 Storage	Bins, files, cupboards, closets, etc.
R-S Equipment Elements	Different types of equipment to be included in the solution.
R-1 Major Equipment	Typewriters, telephones, computers, etc.
S-1 General Equipment	Clocks, staplers, drinking fountains, etc.
T-V Ancillary Elements	Different types of elements which while less immediate in the environment, are important factors in an overall environmental system.
T-1 Building Services	Hot air, cool air, cold water, compressed air, etc.
U-1 Major Enclosures	Doors, windows, walls, ceilings, etc.
V-1 General Enclosures	Window coverings, floor coverings, etc.

Appendix C-3 Information Processing Operations

This lists the major types of operations which are possible using the information items in the banks, and which were employed by subjects in the experiment. The operations are listed by main title, with descriptive material indicating the nature and variables involved in each operation. This listing was used as criteria in the design of the apparatus in an attempt to provide for subject ease and convenience of performing these operations.

INFORMATION PROCESSING OPERATIONS	
OPERATION	DESCRIPTION
1. Information Selection	The physical selection and removal of information items from the information bank for use in problem-solving. This should occur more or less continually throughout the process and may involve review of materials in the bank, possibly making comparisons with items previously selected and developing logical criteria for selection or rejection, may also involve comparisons within the information bank either between items in the same category or between items from different categories and locations within the bank.
2. Information Grouping	The physical grouping of items in juxtaposition to each other on a work-display surface to facilitiate comparison or association, to form compound statements, or to indicate conceptual relationships. This should be highly flexible, permitting different size and types of groupings, different physical configurations, forming and reforming groups in different combinations, using the information in different ways and in different applications.
3. Information Relationship	The establishment of different items or groups of items in physical juxtaposition demonstrating more complex relationships and facilitating comprehension and understanding. This should also be flexible, permitting different types and degrees of relationships to be established and described, including hierarchical and subsystem relationships, and allowing individual items or groups to be related in different directions; complex chains or series of relationships may also be described, relationships should also be easily formed and reformed in different configurations.
4. Information Disposition	The further processing of individual information items after selection, including the physical removal and storage of items outside of the major work-display area, and the "flagging" of items to identify items which have been discarded as unsuitable after selection, or which have been given particular importance or priority by the designer-subject.

INFORMATION PROCESSING OPERATIONS continued

OPERATION	DESCRIPTION
5. Information Modification	The addition of information supplementing the material presented on the information items, usually by making some kind of marking or other encoding of information generated by the subject himself. This may be used to specify additional criteria or solution elements not included in the bank. General comments by the subject about his work may also be included; and graphic drawings, sketches, layouts, floorplans, should also be permitted on a limited basis.
6. Information Consideration	Provides the concept of non-activity, the passive operation of looking over assembled information, considering different possibilities, generating new concepts. This acknowledges subconscious information processing on the part of the subject, but does not attempt to interpret this activity, except as expressed in overt work with the information items.

Appendix C-4 Information Processing Dimensions

This lists the recording "dimensions" or variables associated with the various information processing operations by dimension type, with brief explanatory descriptions. These posed particular problems to be considered in developing the recording capability of the apparatus, and represents a general description of the data which was recorded in the experiment.

INFORMATION PROCESSING DIMENSIONS

DIMENSION	DESCRIPTION
A. Identification	The ability to identify different aspects of subject behavior as specifically, unambiguously, and accurately as possible.
1. Information Search	Identification of sets of items under review in the information bank which may or may not be selected at the given time.
2. Information Selection	Identification of specific items selected from the information bank.
3. Information Reuse	Identification of items previously selected and currently being reused in a different grouping or configuration.
4. Item Groups	Identification of groups formed and their item members.
5. Group Relationship	Identification of groups, and individual items considered as groups, involved in relationship configurations, includes item members of groups and type of relationship.
6. Group Disposition	Identification of groups, or items considered as groups, which receive a given type of disposition, includes item group members and type of disposition.
7. Information Modification	Identification of type and contents of modification, and, where appropriate, information items associated with a given modification.
8. Information Consideration.	Identification of consideration occurrance, and where appropriate, type of consideration.
B. Sequence	The ability to identify and specify the order or sequence of occurrance of different events.
1. Sequence of Information Search	The sequence in which different types of information are reviewed in the bank.
2. Sequence of Items Selected or Reused	The sequence in which specific items are taken from the bank or reused in further processing.
3. Sequence of Groups Formed	The sequence in which specific items were placed in groups and in which specific groups were formed.

INFORMATION PROCESSING DIMENSIONS continued	
DIMENSION	DESCRIPTION
4. Sequence of Relationships Formed	The sequence in which groups were placed into relationships, as well as the sequence of completion or establishment of relationships, and, where appropriate, and direction of relationships.
5. Sequence of Dispositions	The order in which different items or groups were handled, and the sequence of dispositions given an individual item or group.
6. Sequence of Modifications	Sequence in which modifications were established, and where appropriate, the evolution of a given modification (as in a layout or drawing); also the sequence in which information items were associated with a given modification.
7. Sequence of Considerations	Sequence of different types of consideration activity and sequence of prior and subsequent activities.
8. Overall Sequence	Order of occurrance of different activities or aspects treated within the design continuum.
C. Duration	The ability to identify and specify the amount of time spent on different activities.
1. Duration of Information Search	Time spent in search activity and on specific sections or subsections of the bank.
2. Duration of Selection Process	Time required to select a given number of items from a given information category, amount of time a specific information item is "active" (being used or reused in problem-solving).
3. Duration of Grouping	Time required to form a given group or series of groups, length of time a given group is left intact before storage or a subsequent regrouping.
4. Duration of Relationship	Time required to form a given relationship or series of relationships, length of time a relationship or pattern of relationships remains "active".

INFORMATION PROCESSING DIMENSIONS continued

DIMENSION	DESRIPTION
5. Duration of Disposition	Time required to perform a given disposition activity, length of time a given disposition remains in effect (particularly with regard to "storage").
6. Duration of Modification	Time required to perform a given modification activity, length of time a given modification (drawing or graphic image) remains "active".
7. Duration of Consideration	Should account for all time not assigned to a given activity, may also involve time for specific types of consideration.
8. Overall Duration	Total time spent in problem-solving, not including scheduled breaks, depending upon individual time for stopping activity.
D. Description	The ability to identify and specify the precise content of modifications supplementing the pre-specified and defined information items.
1. Description of Information Items	The specific content of new information items developed by subjects, or items altered to provide new interpretations.
2. Description of Element Coordinates	The specific coordinates associated with given solution elements when used to locate these elements in two-dimensional space for the final solution (discontinued after first problem).
3. Description of Verbal Notations	The specific content of any verbal messages or notations used separately to clarify work or impressions, or used in connection with drawings or other graphics.
4. Description of Graphic Notations	Specific configurations generated by the subjects in the form of sketches, drawings, layouts or details.
E. Step Behavior	The ability to identify and specify the problem-solving behavior associated with any specific strategy step in the subject's own interpretation. This would apply to all of the dimensions mentioned above.

APPENDIX D APPARATUS DETAILS

These appendices describe the details in the development of the physical apparatus which was used in this experiment to facilitate the use and recording of information item cards, including the alternatives considered, the final apparatus design, and the specific procedures used by the experimenter in working with the apparatus.

Appendix D-1 Test Apparatus Comparison of Alternatives

This lists the various alternative equipment items and configurations which were considered in the design of the apparatus, including the bases for rejection or acceptance of specific alternatives. This is intended to demonstrate the processes involved in applying the apparatus design criteria and to validate the final configuration which was determined.

TEST APPARATUS COMPARISON OF ALTERNATIVES

ALTERNATIVE	DESCRIPTION
DISPLAY-RECORDING SYSTEMS	Alternative approaches which provide for the display and manipulation of information items and the recording of experimental data.
1. Interactive Computer Display System	Could use: "light pens" for graphics and manipulation of information items, storage and display of information statements, automatic recording and printout of data; however too complex a system to be developed given the time and budget allowed.
2. Random Access Slide Projection	Could be used to store and display information items, with automatic or semi-automatic recording of data on review and selection activities, however still very elaborate and secondary system required for item manipulation.
3. Automated Information Item Dispenser	Item cards stored in file, dispensed for use by subjects when code is punched on control board, control used to drive keypunch for simultaneous recording of item selection; again relatively complex, no provision for recording manipulation of items.
4. Automated Time Recorder	Using physical item cards with time punched on card automatically for different operations, similar to a "time clock"; limited in its application, depends on subjects writing additional explanatory information on the cards.
5. Microfilm Camera and Indicators	Physical card is placed in camera field to record identification, time, and usage as indicated by counters set by subject, all in one operation; still too limited and burdensome for subjects.
6. Photographic Recording of Item Manipulation	Alternative selected for use in experiment, continuous or semi-continous recording of item use on display surface, provides data on sequence and duration as well as item identification, involves more complex data reduction.

TEST APPARATUS COMPARISON OF ALTERNATIVES continued

ALTERNATIVE	DESCRIPTION
PHOTOGRAPHIC METHODS	Alternative approaches which could be used for making a photographic or similar recording of item manipulation on a display surface.
1. Videotape Recording	Relatively flexible and equipment easily available, no film processing required; however, difficulty in retrieving data using stop action, frame-by-frame analysis.
2. Continuous Motion Picture Recording	Readily available, provides complete picture of activities, however, data reduction very time consuming due to length of record, number of repetitions of same information.
3. Discrete 8 mm Motion Picture Recording	Cameras readily available, timers could be designed and built on special order, but cost exhorbitant, film image small might be difficult to read.
4. Discrete 16 mm Motion Picture Recording	Selected for experiment, cameras available, timers could be purchased commercially, image large enough, ample film capacity, processing readily available.
DISPLAY METHODS	Alternative approaches for displaying information item cards, includes method of attachment and type of graphic capability.
1. Card Racks	Vertical or vertically inclined holders for information cards, cards held on ledges or slots, easily removed or rearranged; however limited in terms of card arrangement configurations and graphic capability.
2. "Self-Sticking" Display Boards	Use felt or adhesive to attach cards to boards, easy to apply, presumeably relatively easy to remove; however adhesion might not be positive enough and might decrease with reuse, dust, etc., no direct graphic capability.

TEST APPARATUS COMPARISON OF ALTERNATIVES continued

ALTERNATIVE	DESCRIPTION
3. Positive Attachment Display Board	Using tack and cork board or hook-and-loop material, easily and positively attached and removed; materials somewhat difficult to handle, no graphic capability.
4. Graphic Surface, Reuseable Adhesive	Using an acetate or plastic surface with reuseable, rubber or wax adhesive, permitting writing and erasing with felt-tip pens; satisfactory combination could not be located commercially particularly with regard to adhesive reuseable over several applications and removals, and convenient way of erasing felt-tip markings.
5. Metallic Chalkboard Magnets on Cards	Selected for experiment, magnets easy to use, remove, and reuse, chalkboard flexible, simple materials and erasure, markings highly visible, avoid too small scale, magnets relatively difficult to place on cards.
INFORMATION CARD GENERATION METHODS	Alternative approaches for originally recording the information which would be reproduced on the sets of information cards.
1. Handwriting	Relatively easy and neat using a skilled letterer, and highly flexible in terms of size and content; however somewhat laborious and time-consuming, might lack in credibility.
2. Transfer Type	Very professional in appearance, and flexible in size and type face; but extremely laborious for large amounts of information, requires some skill in application.
3. Typewriting	Easy to produce, good appearance, but inflexible in size, without separate enlargement step, and normally too small to be readable on film record.
4. Typewriting with Stick-On Letters	Typewriting for copy read by subject, stick-on letters easily applied by unskilled labor, readable for code identification of information items, selected for experiment.

TEST APPARATUS COMPARISON OF ALTERNATIVES continued

ALTERNATIVE	DESCRIPTION
INFORMATION CARD REPRODUCTION METHODS	Alternative approaches for reproducing information items cards once an original copy has been generated.
1. Off-Set Duplicating	Readily available on campus, inexpensive; but not capable of printing on heavy enough stock for card use.
2. Off-Set Duplicating with Bonding	Using duplicating for printing and then dry mounting or glueing light-weight sheet to heavier stock, not too difficult or expensive; but very time-consuming with large number of cards.
3. Commercial Printing	Capable of reproduction on almost any weight stock; but very expensive for large number of originals.
4. Commercial Silkscreen	Similar to above, but prohibitively expensive.
5. Off-set Campus Printing	Selected for experiment, compromise on weight of stock, still on the light side but o.k. for experiment, a little more expensive than duplicating but within bounds.
INFORMATION CARD STORAGE METHODS	Alternative approaches for storing information cards in information bank arrangement permitting review and selection of cards.
1. Card Files	Available commercially, used for IBM and index cards, box holds cards in position, user must leaf through individual cards; not satisfactory in terms of searching individual cards, and problems of odd card sizes.
2. Rotary Files	Holding individual cards, but relatively easier to search; difficulties anticipated with individual card searches, and attachment and removal of cards.

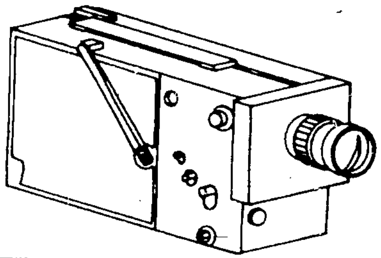
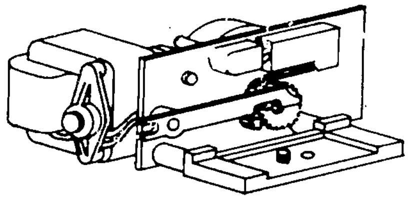
TEST APPARATUS COMPARISON OF ALTERNATIVES continued

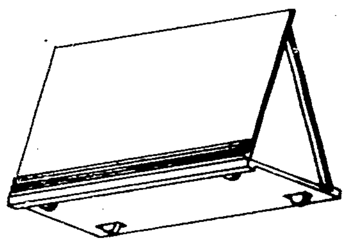
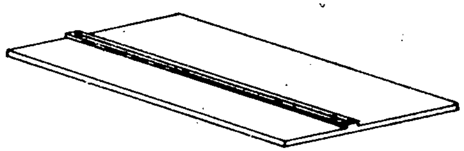
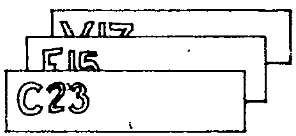
ALTERNATIVE	DESCRIPTION
3. Sheets with Tabs	Pre-cut sheets of light cardboard with tabs or slots to hold cards in positions, while sheets are turned as in a book or otherwise manipulated; would need to be special ordered and do not make use of magnetic capability to hold cards in position.
4. Sheet Metal Racks	Used in library and some commercial operations, available in different sheet sizes, usually retain cards in slots, but could use magnetic attachment, allows for a number of pages to be mounted and turned horizontally as in reading a book; however too cumbersome and expensive with this quantity of cards.
5. Three-Ring Binders with Sheet Metal Pages	Binders readily available 8½ X 11 with 2-inch rings, sheet metal must be purchased and cut to size and punched, but relatively inexpensive, easy to transport and manipulate, although three books are necessary, selected for experiment.
FILM REVIEW METHODS	Alternative approaches for viewing the film record and transcribing the experimental data.
1. Motion Picture Projector	Standard projector not useable since 16 mm cannot usually be stopped for single-frame analysis.
2. Film Editor	Readily available for viewing film one frame at a time; usual manual operation awkward, no capability for keeping count of frames.
3. Single-Frame Projector	Selected for experiment, usually must be special-ordered and very expensive, but available for loan on short-term basis, remote controls for advancing, reversing frame, automatic frame counter.

Appendix D-2 Test Apparatus Design

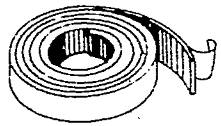
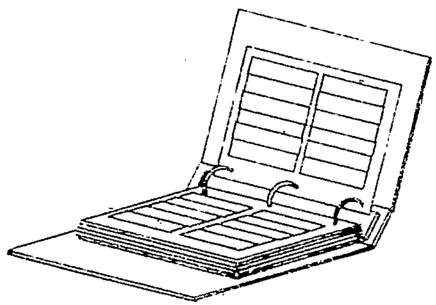
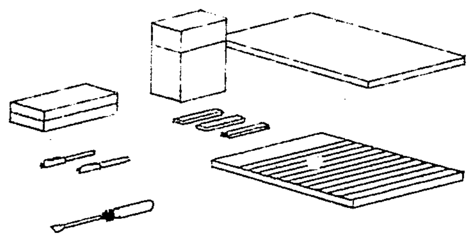
This lists the specific individual components of the DEPIRS apparatus, with illustrative graphics and significant specifications and details of the design, which might be of interest in understanding or reconstructing the apparatus.

TEST APPARATUS (DFPIRS) COMPONENT SPECIFICATIONS

COMPONENT	DESCRIPTION
1. CAMERA 	"Cine-Special Motion Picture Camera" available for load on campus, three cameras, one from Industrial Engineering Department (used in time-motion study), two from Photography Department, used 25 mm lens, focussing on 3" X 5" area at 15 feet, film magazine holds 100 ft. of Tri-X film suitable for room lighting, requires re-winding manually every 10 feet, normally available with reflex viewfinder, single-frame actuator button.
2. TIMER 	"Cine-Special Timer" available on order from the Stevens Engineering Company, Newport Beach, California, $125 each, adapted for use with Cine-Special camera (other models available), attaches with tripod mounting hole, fits over single-frame actuator button, electrically powered motor and cam activates button, timing set for different intervals, 30 second interval setting used in this experiment, somewhat noisy during activation, relatively silent between activations, contains hole for mounting on tripod.
3. TRIPOD 	"Heavy-Duty Tripod", three available on loan from Photography Department, 5" height appropriate for focusing on work surface and for experimenter monitoring, very stable while in use, easy to transport and store, note, camera easily removed for re-winding.
4. CHALKBOARD 	"Magnalinen BF-G8" magnetic chalkboard, eye-saving green, non-glare, 1" X 1" grid lines on surface, composition board backing, aluminum frame, available locally on order, 3' high to accommodate convenient arm reach while seated, 5' long to accommodate cards (should be longer).

<table>
<tr><th colspan="2">TEST APPARATUS (DEPIRS) COMPONENT SPECIFICATIONS continued</th></tr>
<tr><th>COMPONENT</th><th>DESCRIPTION</th></tr>
<tr><td>5. FRAMEWORK
</td><td>"Chalkboard Support Framework" fabricated by the Mechanical Engineering Department shop, a folding support system to hold the chalkboard at a 10-15° angle from the vertical, base of the framework was 2' wide to guard against tipping, castors were included in framework base to permit lateral movement of the board to maintain center of work area in camera field, however, not used due to enlarged camera field, included a chalkrail for chalk storage below chalkboard (chalkboard was raised above table height 4" for ease in use) framing materials treated with neutral varnish for protection of surface.</td></tr>
<tr><td>6. BASE
</td><td>"Apparatus Base" fabricated by the M.E. Dept. shop, provides a base with tracks for the chalkboard support framework with overall dimensions, 3' X 8', made out of 3/4 inch plywood, tracks permit framework to be positioned and stabilized on surface, and moved laterally if desired; framework can be removed for storage and transportation, base also protects surface of supporting desk or table at test site, and includes space for a work ledge and storage of information binders in front of chalkboard, coat of varnish protects surface and provides uniform, neutral work background.</td></tr>
<tr><td>7. CARDS

</td><td>"Information Item Cards" originals produced on standard IBM typewriter with carbon ribbon, code letters applied with 3/4" stick-on letters for visibility on film, original typing used 8½ X 11" sheet for groups of cards sized 1"X 5" normally, with 1½" X 5" and 2" X 5" alternatives, copies printed on light card or index stock, cut to size with small papercutter.</td></tr>
</table>

TEST APPARATUS (DEPIRS) COMPONENT SPECIFICATIONS continued

COMPONENT	DESCRIPTION
8. MAGNETS 	"Magnetized Rubber Tape", 50' rolls, ½" wide, 1/16" thick, with adhesive backing, available locally on order, cut to 1½" lengths with paper cutter, backing removed manually and strip applied to card.
9. CARD STORAGE 	"Hinged Three-Ring Binder", with 2" rings for 8½" X 11" sheets, available from campus stores, light sheet metal storage sheets, material available locally, cut to size, 8½" X 11" and punched for three-holes by M.E. shop at reasonable expense, capacity of binder limited by thickness of sheets and cards with magnets, blank white paper used between magnets and sheets to reduce glare, weight of sheets and magnets in binder considerable, but not excessive, helps to stabilize binder while in use, pages turn vertically so that top page is in camera field and top line of information codes is recorded by camera to indicate search activity.
10. MISCELLANEOUS 	Chalk and erasers are required for making notations on chalkboard, blank paper and felt-tip pens may be provided for making rough sketches of material on board for future reference, a spare set of information cards may be useful in case of loss or accidents, spare magnets may be used for adhering problem statement, layout cards, etc. to board surface, a pad of paper should be available to the experimenter to log times and questions for later reference, and a screw driver is needed to remove camera and timer for re-winding.

Appendix D-3 Apparatus Procedures

This lists the different procedures involved in setting-up and tearing-down the apparatus, and in operating the photographic recording equipment. This is included to demonstrate the relatively simple and convenient operation of the apparatus, and as an aid to others wishing to use the apparatus.

APPARATUS PROCEDURES

SET-UP

A. Evening Before Each Test Weekend

1. Clear test site area of all unwanted materials, stack extra furniture in alcove.
2. Rehang display panels to form experimental booths (it was necessary on initial set-up to reposition four ceiling hooks).
3. Place one worktable in each booth (later place one straight chair in each booth).
4. Re-aim ceiling spotlights to focus on display area above worktable.
5. Move small worktable from faculty office for use by experimenter, position table, large chalkboard, two straight chairs for experimenter area.
6. On initial evening, set-up and try-out major items of apparatus, then store in alcove.

B. Morning Before Each Test Session

1. Place on each worktable: base for apparatus, then chalkboard and frame on base, check position of castors in track.
2. Erase chalkboard surface carefully, rub surface to matte finish, check to make sure no "shadow" images remain from previous work, once a week, damp mop base and frame to clean off accumulated chalk dust.
3. Place three binders with information items on ledge in front of chalkboard, check to be sure that banks are complete and that appropriate strategy step indicator cards are provided, check to see that binders are arranged in sequence of use.
4. Place additional materials in work area: three pieces of chalk and two felt-tip pens in chalkrail, eraser and three sheets of blank paper on ledge.
5. Place experimenter materials in area: extra information cards, extra chalk, pens paper, blank paper for log, screwdriver for servicing camera.
6. Bring in cameras from faculty office, set-up and adjust cameras as per instructions.

TEAR-DOWN

1. Retrieve materials from work areas, chalk, pens, erasers, paper, pack for storage in faculty office.

APPARATUS PROCEDURES continued

2. Replace all information cards selected in ring binders in proper sequence (performed by subjects).

3. Fold up chalkboards and frames, place in storage area with bases.

4. Remove cameras for storage, on weekend, between sessions, unplug timer and carry camera-timer-tripod assembly to faculty office; at end of weekend, disassemble cameras and timers for transport back to Madison, fold up tripods for carrying.

5. Generally clean up after sessions, at end of weekend return small table to faculty office, but otherwise leave furniture, panels, spotlights in place, they were somewhat rearranged during week but there was no set format for classes.

CAMERA SET-UP BEFORE ASSEMBLING

1. Check to insure that lens is firmly seated.

2. Check to insure that magazine aperature door is "open", referring to position of knob on front of camera.

3. Set shutter speed at "24" using knob on timer side of camera.

4. Check to insure that shutter fade-out is on "open", using lever and markings on side of camera.

5. Use button on front of camera to run off approximately 5' of film, check camera operation.

CAMERA WINDING

1. If necessary remove timer from camera, by undoing mounting screw in base (usually first remove camera and timer from tripod), then attach winding handle on side of camera using screw in handle, notch in handle may be used for tightening once screw is started.

2. Wind camera approximately 10 turns in counter-clockwise direction, until bell rings or shutter cperates.

3. Remove handle, by reversing above procedure, reattach timer and tripod.

ATTACHING TIMER

1. Pull out single frame actuating button on side of camera.

2. Position timer on side of camera so that arm on timer engages actuating button.

3. Adjust timer position so that button is firmly engaged by timer arm.

APPARATUS PROCEDURES continued

4. Screw base of timer onto base of camera, tighten with screwdriver.
5. Manually depress timer arm to insure movement is free.
6. Plug timer cord into baseboard outlet or extension cord, turn on timer, check that actuator button is operating completely, if not, adjust position of timer.
7. Turn off timer until start of actual session.
8. Thread screw in tripod into mounting hole in base of timer, adjust lateral and vertical angles on tripod mount so that camera is aimed in general direction of display board.

FOCUSSING CAMERA

1. Determine f-stop using light meter (only once for artificial lighting).
2. Open f-stop to full-open position, depress button operating reflex viewfinder.
3. Use viewfinder to correctly position camera, framing in display board, if necessary move tripod forward and back to achieve correct framing, use tripod mount adjustments to fix camera angle, tighten adjustments.

4. Adjust focus on lens until image is sharp, use sample information cards on display board for test image, verify distance shown on focus knob with actual distance between camera and display board (use tape measure).
5. Close down f-stop to predetermined setting, recheck focus.
6. Manually operate single frame actuator, check that button on reflex finder "pops up".

RUNNING CAMERA

1. Start camera timer at beginning of experimental session (note camera has been pre-wound and focussed).
2. Make a note of film counter reading on back of camera.
3. Periodically, 2 or 3 times per hour, check camera operation, note that timer is operating, that shutter mechanism is being actuated, recheck focus, particularly if camera may have been jostled.
4. Each hour check film counter reading to insure that film is moving properly.
5. When necessary rewind camera as per instructions, check all settings after rewinding.
6. At end of session, stop timer, and check film used against actual working time.

APPENDIX E SUBJECT INTERACTION DETAILS

These two appendices describe the two major inputs of subject verbal responses in this experiment; specifically, questions asked during the experimental sessions, and responses to questions asked by the experimenter in a final "debriefing" meeting with all subjects.

Appendix E-1 Question Log

This lists the questions asked by subjects and the responses given by the experimenter, as they occurred at different specific times, on different days of the experimental test sessions. As demonstrated in this listing, most of the questions were not of major substance, and did not appear to have important impact on the data, and after the first day of the second weekend, there were no further questions asked, suggesting that the subjects were confident with their understanding of what they were being required to do.

QUESTION LOG

QUESTION	RESPONSE
<u>Saturday, April 29</u>	
12:06 Subject #3	
Q. Where do we put the information cards when the chalkboard is filled?	A. Either on the upper part of the board or on the table.
12:40 Subject #3	
Q. Where can I find information to describe details in the design process?	A. Information Bank section B-5.
3:30 Subject #3	
Q. How can I express "conceptual reasoning" as distinct from the concept itself?	A. This should be expressed by the grouping of information.
6:15 Subject #2	
Q. Can you use chalk drawings to illustrate room layout?	A. Try to use "dimensional coordinates" as far as possible, to facilitate coding.
Q. Can you write directly on the floor plan grid cards provided in the information bank?	A. No use scratch paper or chalkboard.
<u>Sunday, April 30</u>	
11:20 Subject #5	
Q. Where do you put information cards when the board is filled?	A. On the table.

QUESTION LOG continued

QUESTION	RESPONSE
11:25 Subject #6	
Q. Should you leave the previous strategy step card on the board, when the card is added to show the next step?	A. Remove previous step card, leave only current step card on board surface.
11:36 Subject #4	
Q. When going to the next strategy step, should information cards from the preceeding step be left on the board?	A. Yes, if possible.
1:35 Subject #6	
Q. Should you draw lines (indicate relationship) between problem requirement cards and cards indicating aspects of "target solutions"?	A. Yes, if possible.
1:05 Subject #4	Comment: Don't overlap information cards because of interference with recording.
1:05 Subject #5	Comment: Make chalk lines indicating relationships darker to aid recording.
2:10 Subject #5	
Q. Are floor plans (spatial relation of elements) to be used only in the final stages of design?	A. Use them anywhere they are appropriate.
3:52 Subject #4	
Q. Do we have to specify solutions in terms of spatial relation of elements or can we just list the elements?	A. Initially, you need only list elements, but you will probably have to arrange them eventually.

QUESTION LOG continued

QUESTION	RESPONSE
5:00 Subject #4	
Q. How can you describe a solution with two different floor levels or "stories"?	A. Use two floor plans and indicate the relationship.
5:20 Subject #5	Comment: Remember to use information cards to identify elements in graphic drawing.
5:45 Subject #4	Comment: Clarify isometric drawing, use coordinates to locate solution elements.
<u>Monday, May 1</u>	
2:22 Subject #8	
Q. Should I select all the Ergonomic Factor cards since they are all likely to be important?	No, select only those which relate to a critical design decisions (note: this was stressed in orientation sessions and in most cases promptly ignored).
3:00 Subject #8	
Q. How can I begin to identify a solution?	A. Use either "Solution Concepts", "General Element Types" or specific solution element alternatives.
5:45 Subject #8	
Q. What do the "stars" mean when used with K-1, Standard Elements?	A. Elements which are frequently used but are not universally accepted.
<u>Saturday, May 6</u>	
2:45 Subject #1	
Observed: error in information card where "door" was mistakenly typed as "desk".	Note: This was the last exchange with subjects and experimenter for the duration of the experiment.

Appendix E-2 Debriefing Session

This lists various questions asked by the experimenter and the subject responses as recorded at an evening session which was intended to elicit subject responses to the experiment. These responses should provide a rich resource of opinion in understanding and interpreting the results, and in restructuring the experiment in further applications.

DEBRIEFING SESSION

A. General Impressions

#5 Wondered why they used different strategies, some discussion.

#6 Why not make combination of information items easier, facilitating the formation of "expressions"; after a few hours eveything in the information bank seems "equivalent".

#2 Isn't there some way to permit questioning of a "client" for additional information or clarification.

#4 and #9 More space is needed for storage and display of information cards.

#9 The information bank is inhibiting, some categories such as "general information" should have been displayed as a whole, larger pages are needed.

#8 A more comprehensive index for the information bank is needed.

#5 The first test session was difficult, need prior experience working out an "example".

#5 Found "solution concepts" and "general information" useful for describing solution.

#3 and #7 Research information was incomplete, need more details on "color" "psychological variables" etc., not enough information for meaningful development.

#2 Why were "rooms" used for test problems, why not specific elements.

B. How Well Did Experiment Capture Your Real Problem-Solving Processes

#6 The limited format forced processes to be more logical than usual.

#7 It provided a general picture, but images and combinations still stored in mind.

#7 Difficulty in retrieving items previously used made it difficult to demonstrate corrections.

#1 Felt really "tied down" in solving problems, but doesn't know why exactly.

All: Third session felt like essentially "cranking out" a solution, less satisfied with results.

#2 Situation was artificial in sense that designers do not usually work continuously for 6 hours, usually work for a while and then take a break.

DEBRIEFING SESSION continued

#6 "Real" designers reach dead-ends, but here there was a pressure to use everything.

#4 and #7 Felt tied down by strategy, need to go back and redo something done on previous steps, sometimes ignore strategy do it anyway.

#7 Need to draw, express ideas graphically, analyze drawings.

#7 Miss having "sounding board" talking to other people about problem.

D. How Different was This From Your Normal Strategy (Process)

#1 Usually take more breaks, use more data ordered differently.

#3 No way to show continuous evaluation process.

#4 Felt very similar to normal.

#5 (15-step) Not used to "target solution" approach.

#7 Needed to use "target", data not conducive to "brainstorming".

C. Did You Feel You Could Follow Strategy

All: Most subjects felt they had been able to follow their strategy pretty well.

#6 (15-step) After step 10, tasks became very complicated, and tended to revert to own strategy.

#4 (15-step) Difficult to perform "information processing" as a separate step.

#7 (5-step) had difficulty with "evaluation".

#7 Admitted that he had been influenced by prior contact with "IDEAL" strategy (similar to 15-step).

E. Did You Learn Anything

#7 After first session, it was fun to work with own data bank.

#4 Felt that he relied too heavily on data bank in first session.

#6 Felt lack of "context", had difficulty working without particular situation to be designed for.

#9 Felt data was too clear, lead you down a path to solution.

#4 "Problem identifiers" were too specific narrowed problem too fast.

All: more information and concepts in bank than they would have tought of.

DEBRIEFING SESSION continued

#4 Experiment made him more conscious of strategy steps which he used inherantly.

#3 Felt that data bank would have been impossible in real world.

#5 Learned that you could solve a design problem in 8 hours.

F. How Did You Feel About Grouping

#9 Usually use grouping anyway, roughly the same.

#4 Don't usually use "chain", linear organization implied by formal means.

G. How Did You Feel About Information Bank

#4 Not enough statements (concepts).

#6 Usually designer has to make results explicit but not process.

#4 Need to have better means of identifying what you are doing, better process descriptors, easier to find.

#7 Information on solution details not useable within time limit.

All: Need to go back to information previously selected.

#8 Coordinate system for spatial arrangements not feasible.

H. How Should It Have Been Done Differently

All: Need broader problem definitions.

All: Need more complete human factors and psychological data.

All: Need better process descriptors.

All: Need ways of describing three-dimensional space.

I. What About the Apparatus or Method In General

#4 Generally comfortable with it, but could be more mechanized.

#1 Hard to sit down for 6 hours, hated it!

APPENDIX F DATA PROCESSING DETAILS

These appendices describe the method which was employed in translating the data on information use on the film record into a numerical code suitable for keypunching and machine analysis, including the coding scheme and format, and the conventions applied in using the coding method.

Appendix F-1 Coding Method

This lists the code numbers and column positions associated with different aspects of the data record, as adapted for use with the first 37 columns on an 80 column standard IBM card. In practice, reference was made to this code in transcribing data from a projected film image to a coding sheet for subsequent keypunching, the description notes indicate the type of information and the method used to generate specific code numbers.

DATA CODING METHOD

CODE	DESCRIPTION
IDENTIFICATION	A means of labeling all of the cards included in a given test session for an individual subject, repeated on each card.
Column 1 - Subject Code	A number from 1-9 assigned to each of the nine test subjects, used through the data.
Column 2 - Strategy Code	A number to indicate the strategy used by each subject, and by extension the day of the week on which the session was held.
1 = 10-Step (Saturday)	
2 = 15-Step (Sunday)	
3 = 5-Step (Monday)	
Column 3 - Problem Code	A number to indicate the test problem related to the given data set, and by extension the weekend on which the session was held.
1 = Faculty Office	(first problem)
2 = Snack Bar	(second problem)
3 = Conference Room	(third problem)
FRAME (TIME)	An identification of the specific frame of the data film record on which a given item of data is located, since a frame was taken every 30 seconds this also indicates time.
Column 5-7 Frame Number	A number from 1 - 999 read directly from a frame counter incorporated in the film projector, which was reset to 0 at the beginning of each individual test record.

DATA CODING METHOD continued	
CODE	DESCRIPTION
STRATEGY STEP	An indication of the strategy step which a subject believes he is using at any given point in time, used on every card.
Columns 9-10 - Step Number	A number from 1-15 read from strategy step cards, placed by subjects on the display surface.
INFORMATION ITEM	An identification of the information item cards which show a change on any given frame, either by selection, grouping or regrouping, movement to storage, etc., shown one item per card.
Columns 11-13 - Item Code	A two or three character code, beginning with an alphabetic character and followed by one or two digits, read directly from the code number placed on each individual card.
INFORMATION STATUS	An indication of the status of a given information item, showing whether it is being selected for the first time, or if it was selected on a previous frame and is now being reused in some way.
Column 15 - Status Code	A number used to indicate item status as follows:
1 = Initial Selection	Usually apparent by observation and some recall, may involve rechecking data already coded.
2 = Subsequent Reuse	As above, identified by observation or rechecking.
INFORMATION GROUPING	An indication of the group membership of each information item; by convention, each item selected or reused is assigned a group number for use in further processing, items in the same group are assigned the same group number.

DATA CODING METHOD continued

CODE	DESCRIPTION
Columns 17-19 - Group Number	A number from 11 - 999 assigned by the data coder in sequence starting with the first item and group on the film record, a new number is used for each subsequent group which is formed, groups were identified by observation, usually based on proximity or physical layout, occasionally supplemented by chalk marking, groups were assumed to be in existence until physically rearranged, items added at a later date were given the same group number.
GROUP SEQUENCE	An indication of the order or sequence in which items were placed in a specific group, used due to the absence of card sequence numbers in the data record, as a safety precaution.
Columns 36-37 - Sequence Number	A number from 1 - 999 assigned by the data coder based on observation of item position in a group, sequence was maintained even when items were added at a later time.
GROUP RELATIONSHIP	An identification of pairs of groups involved in some type of relationship, and in some cases individual groups involved in disposition activities.
Columns 21-23 - Primary Group Number	A number from 11 - 999 identified by the data coder as the group number previously assigned to a given grouping of information items which are involved in a relationship or disposition operation. Where a directional relationship is indicated, this group represents the origination or "tail" of a real or hypothetical "arrow", all types of relationship were determined by observation of physical configurations, usually specifically described by chalk markings.

DATA CODING METHOD continued

CODE	DESCRIPTION
Columns 27-29 - Secondary Group Number	A number from 11 - 999 identified by the data coder as above, representing the second member of the pair of groups involved in a given relationship. Not used for disposition.
RELATIONSHIP TYPE	An identification of the type of relationship as derived from the coder's interpretation of the subject's intentions, always used with pairs of groups.
Column 25 - Relationship Code	A number from 1 - 6 identified by the data coder comparing a given configuration with a pre-arranged identification code, which is described as follows.
1 = Series Relationship	A directional relationship between primary and secondary groups, usually indicated by an "arrow" drawn by the subject from primary to secondary, but may also represent more general sequence or hierarchical relationships.
2 = General Relationship	A non-specified relationship without directionality, indicating some general affinity. This was very common, frequently portrayed by a single line between groups without arrowhead, but also suggested by physical proximity of groups on the display surface.
3 = Combination Relationship	A special case, usually indicated by verbal comment (chalk message) or special graphic notation.
4 = Separation Relationship	Another special case, usually indicated verbally.
5 = Feedback Relationship	Usually indicated by a line or arrow reaching back to a previously established configuration.
6 = Conflict Relationship	Rare, indicated by verbal comment.

DATA CODING METHOD continued

CODE	DESCRIPTION
DISPOSITION TYPE	An identification of the type of disposition used by a subject, refers to groups listed in Cols. 21-23.
Column 31 - Disposition Code	A number from 1 - 5 identified by the data coder based on a pre-arranged identification code as follows:
1 = Storage	Identified by observation of physical removal of items to a remote area of the display surface, or placement on the table out of the camera frame.
2 = Review	Items which have been previously selected and stored, which are returned to the active area of the display surface.
3 = Priority	Items highlighted by the subject, usually with a verbal comment, or by a graphic notation.
4 = Discard	Item previously selected and subsequently rejected as inappropriate or otherwise unuseable, usually indicated by verbal comment.
5 = Conflict	Items cited by subject as being in general conflict with other information items being used, usually noted verbally.
VERBAL TYPE	An identification of the general type or category of verbal message as identified from the content, specific messages were not transcribed from the film record at this time.
Column 33 - Verbal Message Code	A number from 1 - 9 identified by the data coder, based on a pre-determined content code as follows:
1 = Title	The first frame on any data record, indicating the presence of identification information.

DATA CODING METHOD continued

CODE	DESCRIPTION
2 = Eliminate	Indicates item or items being discarded (ses Disposition).
3 = Designate	Indicates addition or clarification of information item or items, infrequently used.
4 = General	Indicates a general comment or observation, usually adding to or modifying an existing information configuration.
5 = Special	Indicates a comment or observation of some importance, clarifying or modifying work being done.
6 = Lunch	A standard notation indicating the point at which the lunch break occurred.
7 = Evaluation	Indicates a comment or clarification of the evaluation process.
8 = Revision	Indicates solution revisions, noted but not actually performed.
9 = End	A standard notation, always the last card in the record of a given session.
GRAPHIC TYPE	An identification of the general type or function of a given graphic image generated by the subject, specific graphics were transcribed from the record only with regard to final solution configuration.
<u>Column 35 - Graphic Function Code</u>	A number from 1 - 9 identified by the data coder based on a pre-determined code as follows:
1 = Area Configuration	A schematic or functional representation of a room area, without specific size or shape indications, frequently occurring as a "bubble" diagram.

DATA CODING METHOD continued

CODE	DESCRIPTION
2 = Annotated Floor Plan	A detailed layout of the room area, indicating the location of specific elements.
3 = Circulation	A drawing indicating circulation paths either schematically or on the floor plan.
4 = Sketch Floor Plan	A drawing indicating general size and shape of the floor plan, with minimal specification of solution elements.
5 = Interaction	A schematic representation of interactions between functional areas, infrequently used.
6 = Detail	A detail drawing of a specific room area or solution element.
7 = Paper Notes	Indicates occurrance of subject sketches on blank paper, displayed for camera record.
8 = Elevation	A drawing in elevation or section showing vertical dimensions, usually to complement a floor plan.
9 = Perspective	An isometric or other perspective rendering of a solution, indicating area and solution elements in "pictorial" form.

Appendix F-2 Coding Conventions

This lists a number of conventions qualifying the application of the coding method as used in practice by the data coders.

CODING CONVENTIONS

A. Frame (Time)

1. Precise minute-by-minute recording of data was not considered to be essential or practical, rather frame designations were used to indicate "sequence" within a gross time framework.

2. In this time framework 10 frames or five minutes was considered as a significant order of difference to be captured in the record.

3. Significant pauses or breaks in activity were by convention indicated by a break in continuity of at least 10 frames, otherwise frame numbers were usually used as follows:

4. When groups of items were being selected from the information bank it was usual practice to wait until an obvious break in the process and then list all selections in the last frame in which they occurred.

5. When grouping or relationships were generated more or less continuously, it was customary to wait until a pause and then record all transactions in the last active frame.

6. Where groups or relationships were formed and reformed in a continuous process, the original formations were recorded in the frame prior to the reformation.

7. In order to identify sequence, a different, unique frame was used, sometimes artificially, to distinguish: changes in strategy step; transitions between selections or groupings and relationships; dispositions; verbal and graphic notations.

8. Similarly, where appropriate, different frames were used to list the members of different major groupings, with each group listed under a separate frame number.

B. Information Items

1. The identification of specific items was almost invariably unambigous; rarely, where cards were obscured by body movements or overlaps, the best approximation of card identify was used.

2. The sequence of listing information items was usually based on direct observation of selection or physical sequence within groupings on the display board, occasionally it was necessary to approximate sequence when the actual sequence was concealed by body movement or overlap.

C. Grouping

1. Identification of groupings was usually unambiguous, where some question occurred it was assumed that the greater number of groups would maximize information.

CODING CONVENTIONS continued

2. Where a subclass heading or process descriptor card was used with a group of general information items, it was usual practice to consider these as separate "groups" and then indicate the relationship.

3. Where individual item or items in a group were given special treatment, such as "priority" or "discard" they were reassigned to separate groups in order to indicate their unique disposition.

4. Where relationships were shown or implied between items in a larger grouping, the individual items were reassigned individual group numbers in order to indicate their relationship.

5. In some cases where a large number of items, usually solution elements were selected without any specific relationship or grouping pattern, all the items would be assigned a single group number.

D. Relationship

1. In most cases, relationships were determined by deliberate, direct indications by the subject, some assumptions were made for "general" relationships, but simple co-occurrance on the display surface was not sufficient to establish a relationship without some further indicator.

2. Most relationships were identified as either "series" or "general" based on the presence or absence of directionality other alternatives were used only when specifically indicated.

3. Continuous "chains" or sequences of relationship were indicated by overlapping pairs of relationships, where the "secondary" group for a prior "primary" group, was used in turn as a "primary" group for the next group in the sequence.

4. A specific convention was used to indicate sets of elements included in the solutions, by relating their group numbers to a common number associated with the "floor plan grid card" selected by the subject.

E. Disposition

1. When large numbers of groups were removed to storage at the same time, the group numbers were listed in numerical sequence on the same frame number, for ease in handling.

APPENDIX G COMPUTER ANALYSIS DETAILS

These appendices describe the use of the data cards which were generated using the coding method and conventions, with a computer program designed to tabulate summary data for each test session, and a second program to print out the data for each session in a form convenient for manual tabulation.

Appendix G-1 Computer Tabulation

This lists the output from a computer program developed to tabulate different aspects of information item selection, reuse, and grouping as found in the data, with descriptive information clarifying the type of tabulations and the means used to make the tabulation.

COMPUTER TABULATION

OUTPUT	DESCRIPTION
A. Item Selection	A tabulation of data on the selection of information items from the bank.
1. Total Number of Information Items Selected by Subject	A count of the number of items in the data record with a "1" Status Code.
2. Listing of Code Numbers of all Items Selected	Items identified as above, program stores and alphabetizes item code numbers, prints out numbers as given in the data.
3. Total Number of Information Items Selected by Subclass	Subclasses based on code number configuration, usually by different alphabetic character and "tens" digit, pre-specified for the program, counts items selected with a given subclass characteristic.
4. Total Number of Information Items Selected by Class	As above, classes determined by alphabetic character A - Z.
B. Item Reuse	A tabulation of data on the use of items, previously selected.
1. Total Number of Items Reused One or More Times	A count of the number of individual items with an associated "2" status code, occurring one or more times in the data record.
2. Listing of Items Which Were Reused and the Frequency of Reuse	Items identified as above, with a counter for each number recording and printing the total number of occurrances of the "2" status code, program stores and alphabetizes item codes.
3. Frequency of Item Reuse by Subclass	Subclasses established as above, counts the number of "2" Status Codes associated with each subclass.

COMPUTER TABULATION continued

OUTPUT	DESCRIPTION
4. Frequency of Item Reuse by Class	Similar to above.
5. Total Number of Incidences of Reuse	A count of the total number of "2" Status codes in the data record.
C. Groupings	A tabulation of data on the groups formed in the data record.
1. Total Number of Groupings in Which the Items were Selected	A count of the groups in which the first occurrance of the group "number" was associated with an item having a "1" status code.
2. Total Number of Groupings in Which the Items were Reused	As above with the first occurrance of the group number associated with a "2" status code item.
3. Listing of Group Numbers in Which Items were Selected	Program stores and prints out the numbers of groups identified as above.
4. Listing of Group Numbers in Which Items were Reused.	Similar to above.
5. Listing of the Groups by Number with the Code Numbers of Group Members.	Program stores and prints each group number and the codes of the items having that group number, wherever they occur in the record.
D. Group Measures	Statistics computed from the data used in the previous section.
1. Total Number of Groups Formed.	A count of the total number of groups identified in #5 above.

COMPUTER TABULATION continued

OUTPUT	DESCRIPTION
2. Total Number of Items in Selection Groups	Number of items in group counted from #5 above, selection groups identified as in #1 above.
3. Total Number of Items in Reuse Groups	Similar to above.
4. Average Size (Number of Items) of Select Groups	Mathematical computation from above.
5. Average Size of Reuse Groups	See above.
6. Average Size of All Groups	S. .ilar to above.
7. Smallest and Largest Number of Items in Groups Formed	Computed for each group type.
8. Standard Deviation of Group Sizes.	Computed for each group type.
E. Runs	A tabulation of data and statistics on sequences of groups formed, without any intervening type of different activity.
1. Total Number of Runs Formed	Computer identifies beginning and ending of sequence of groups formed by changes in pattern of data record, counts the number of sequence occurrances.
2. Listing of Group Members in Each Run, and the Number of Groups included in Each Run	Program prints out and counts the group numbers in each run series.
3. Average Run Size (Number of Groups)	Mathematical computation from above.

COMPUTER TABULATION continued

OUTPUT	DESCRIPTION
4. Largest and Smallest Run Size	See above.
5. Standard Deviation of Run Size	See above.
F. Total Number of Records (Cards) Processed for Each Test Session	A tabulation made of the total number of data cards in each session, note that each item selected, used in a group, each relationship pair, disposition, verbal or graphic notation required a different data card.

Appendix G-2 Computer (Attribute) Listing

This is a listing which describes the rearrangement of the data punched on the cards, printed in separate columns for convenience in review and manual tabulation. Since this program was only used to provide printing instructions it was relatively simple to generate and run.

COMPUTER (ATTRIBUTE) LISTING

ATTRIBUTE	DESCRIPTION
1. Card Number	Automatically generated by processor, sequential numbering for all cards processed, differences may be calculated for specific parts of the record.
2. Problem Identification Number	Identifies each test session.
3. Strategy Step Number	Identifies activities associated with a given strategy step.
4. Frame Number	Indicates time for any given activity or subsection.
5. Items Selected and Their Group Numbers	Supplements tabulation of selection data, may be used for review and secondary pattern identification.
6. Items Reused and Their Group Numbers	Similar to above.
7. Pairs of Groups "Series" Related	May be used to develop data on relationships.
8. Pairs of Groups "General" Related	See above.
9. Pairs of Groups other Related	See above.
10. Group Numbers and Types of Disposition	May be used to develop data on dispositions.
11. Verbal Type Code	See above.
12. Graphic Type Code	See above.

APPENDIX H EVALUATION DETAILS

These appendices describe details related to the evaluation of solutions generated by the subjects in the course of the experiment. Specifically, the appendices cover the major materials presented to the evalutors for use in decision making including: evaluation criteria; a summary of problem requirements given to subjects; solution drawings; and lists of specifications produced by the subjects.

Appendix H-1 Evaluation Criteria

This lists the six criteria and their definitions as provided to the evaluators, accompanied by descriptive information indicating the relevance of each criterion.

EVALUATION CRITERIA	
STATEMENT	DESCRIPTION
1. Comprehensive Is the solution inclusive? Does the solution take into account and make provision for the different user activities and other considerations as given in the problem description.	An overall test of the subject's ability to work with the materials in solving the problem, an important consideration in actually satisfying the design problem.
2. Effective Is the solution workable? Does the solution make adequate provision for the activities and other considerations as given in the problem statement.	It is necessary not only to cover all the requirements, but to cover them well; important if the solution is not too comprehensive, but provides good solution for what it does cover.
3. Efficient Is the solution economical? Does the solution demonstrate considered management of the space, resources, and user energies in meeting the problem requirements.	A basic consideration and while this was played down in the problem description, a certain level of economy is always desirable, may include a trade-off between solutions comprehensive or effective but not efficient, and vise versa.
4. Aesthetic Is the solution attractive? Is the solution likely to be emotionally satisfying to the users.	Essentially redundant with #2, but included because of traditional importance in the field, requires a subjective judgement by the evaluators.

EVALUATION CRITERIA continued

STATEMENT	DESCRIPTION
5. Innovative Is the solution imaginative? Does the solution creatively express new or different approaches to the problem.	A consideration given importance in the problem statement, and regarded by the experimenter as an important test of strategy effects.
6. Complete Is the solution thorough? Does the material generated by he subject provide sufficient information both in precision and scope to give a reasonably coherant, understandable picture of the solution.	A more mechanical consideration, related in part to subject working habits, but also regarded as an important characteristics of strategy effects.

Appendix H-2 Problem Requirements

This lists the major requirements used by the subjects in problem-solving, and by the evaluators in judging the solutions, including: general requirements applicable to all problems; and the specific requirements associated with individual problems; as derived from the individual item cards supplied in the information banks and the problem statements given at the beginning of each problem-solving session.

PROBLEM REQUIREMENTS

TYPE	REQUIREMENT
GENERAL REQUIREMENTS	Subjects were given specific requirements for each test problems, however, some general requirements were repeated for each problem.
Orientation	"The University of Wisconsin is trying to look ahead at development over the next ten years. A very far-sighted administrator has asked you to consider the following design problems. For each problem he has specifically asked you to rethink the problem situation and to disregard the present approaches to the problem except as a reference."
Objectives	A. The solution should meet the operational requirements of the activities for which it is planned.
	B. The solution should not be lavish but should include all aspects justifiable in terms of operational considerations.
	C. The solution should meet and support the psychological and physiological requirements of the users.
	D. The solution should be innovative in the sense that it points the way toward future potentials of design in the real world.
Administrative policy	A. While it is open to broad interpretations, it is assumed that present teaching and research methods and relationships will remain fairly constant.
	B. Relative economy should be used in selecting elements and construction methods, but all necessary elements should be used.
	C. Space should be adaptable to account for future changes in teaching or research methods or future building uses, but this should not be a serious limitation.
	D. There is no standard set for square footage, either maximum or minimum, beyond what is actually required.

PROBLEM REQUIREMENTS continued

TYPE	REQUIREMENTS
	E. There are no policy constraints on type of furnishing, style, atmosphere, etc.
	F. Building codes and other standards need not be considered at this time, but will be adapted to proposed designs.
Technical Limitations	A. Assume the present state of technology as you know it, with some logical extrapolations.
	B. The location or fabrication of most elements and configurations should be possible, unless real and serious problems are obvious.
	C. The identification of specific compatible elements is not too important, details can be worked out later.
Building Site	A. The building as a whole will be designed later, there are no specific restrictions on configurations, size, materials services, etc.
	B. There are no a priori restrictions on location of the problem facilities or on the location of related facilities or services in the building.
Natural Site	A. The climate is subject to seasonal variations similar to those in Milwaukee, Wisconsin.
	B. There is a good natural view in all directions, in pleasant semi-urban surroundings.
	C. Adjacent buildings are widely spaced and need not be considered in relation to this design.

PROBLEM REQUIREMENTS continued

TYPE	REQUIREMENTS
PROBLEM I	
Problem	"Design a work area for a single faculty member"
User Requirements	A. Faculty must carry out research activities, surveying information, developing and testing hypotheses, communicating results.
	B. Faculty must prepare teaching materials, surveying past notes, collecting new information, organizing information for presentation, developing teaching aids.
	C. Faculty must carry out bureaucratic responsibilities, learning rules and regulations, filling-out forms, keeping records, reading reports.
	D. Faculty must work with students, evaluating their work, discussing problems with them, providing advice and guidance.
	E. Faculty must be able to carry out personal activities, relaxation, recreation, eating, discussion, hygiene.
	F. Students must be able to communicate with faculty members, present work, receive guidance.
	G. Other faculty and staff must be able to consult the faculty member, work on joint problems, exchange information.
	H. Maintenance workers must be able to carry out their responsibilities for cleaning, upkeep, repair.
User Characteristics	A. The faculty member has little or no work space available to him outside of his office.
	B. The faculty member has a relatively wide range of interests; both personal and professional.

PROBLEM REQUIREMENTS continued

TYPE	REQUIREMENTS
	C. The faculty member can relate to technology and if it is available, make good use of it in his work. D. The faculty member relates to culture and mod or avante garde styles, he considers cultural life and experiences to be very important. E. Students would like to make more use of faculty members as a resource, discussing academic questions and problems. F. Students are usually uncomfortable when dealing with faculty members and are very conscious of and inhibited by their subordinate position. G. Students are becomming less competitive and are interested in group projects and discussions. H. Staff consider themselves as co-workers whose time and effort are valuable and who deserve facilities just as adequate as those provided to faculty. I. Co-workers and other visitors to the faculty work space may be of similar background and able to relate on an informal basis. J. The time and energies of maintenance workers are important and efforts should be made to facilitate their work.
PROBLEM II <u>Problem</u>	"Design an informal food service located in a university classroom building. Food will be prepared at a central location either by university food service or by an outside contractor, few if any personnel are available for regular service in the snack area. The facility should be

PROBLEM REQUIREMENTS continued

TYPE	REQUIREMENTS
	open 24 hours per day, and should accommodate a peak load of 100 people. The use of vending machines is suggested as a possible approach."
User Requirements	A. Users must be able to obtain nourishment, retrieving and consuming food.
	B. Users must be able to meet and talk with each other, engaging in large and small group discussions, exchanging ideas.
	C. Users must be able to carry out educational activities, obtaining information, taking notes, working problems.
	D. Users must be able to work together on joint problems, discussing problems, looking over work together.
	E. Users must be able to engage in recreational activities, playing games, reading, resting.
	F. Users must be able to store and retrieve personal belongings which are brought into the area, but which are not needed while dining.
	G. Service personnel must be able to restock and service food dispensing equipment.
	H. Service personnel must be able to maintain the area, disposing of refuse and keeping all survaces clean.
User Characteristics	A. Most users will require one or more food items irrespective of their other requirements.
	B. Most users will require seating and some work surface for dining and other activities.
	C. Most users will bring some personal belongings with them, a purse, knapsack, coat, etc., which have to be stored while they eat.

PROBLEM REQUIREMENTS continued

TYPE	REQUIREMENT
	D. Most users will arrive in groups of two or more and wish to sit together or join with groups of friends.
	E. Most users are taking a break from their educational or office activities and welcome a change of scene.
	F. Most users are in touch with youth culture and with current styles and idioms.
	G. Many users will have some resentment against the university power structure and feel that the university cuts corners in providing public services.
	H. Many users are serious students and use the snack bar as a chance to put in extra study and cannot relate to excessive chaos or uproar.
	I. Some users consider the taking of nourishment as a job which must be done, and want the job to be as simple and straight-forward as possible.
	J. Service workers have a job to do, and their needs should be considered just as much as those of the patrons.
PROBLEM III	
<u>Problem</u>	"Design a group meeting-presentation space for a typical (social science) university department. The space should accommodate various sized groups up to 20 people."
<u>User Requirements</u>	A. Faculty and/or students must be able to hold formal meetings, with discussion, possibly a chairman, some visual aids.
	B. Faculty and students must be able to conduct seminars, presentations of student work, audio-visual aids, etc.

PROBLEM REQUIREMENTS continued

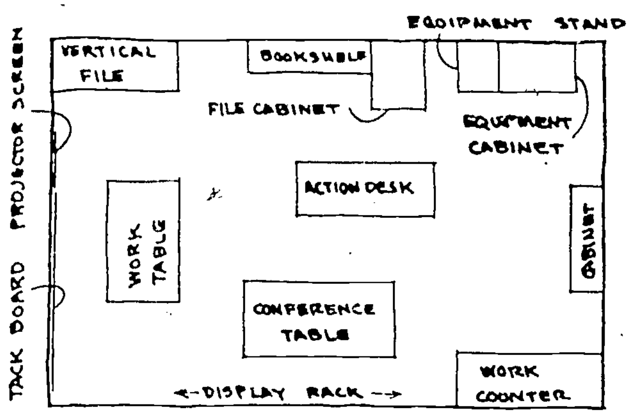
TYPE	REQUIREMENT
	C. Faculty and students must be able to have special presentations by visiting lecturers, consultants, etc., with extensive audio-visual aids.
	D. Faculty and/or students must be able to hold informal discussions or bull sessions which may include some graphics.
	E. Faculty and students must be able to conduct planning meetings, with discussion, visual aids, sketches or diagrams, solution plans.
	F. Faculty, students, staff, must be able to have audio-visual activities, viewing films, televiewing, listening to radio or recordings.
	G. Faculty, students, staff, must be able to use the space during lunch hour for informal dining, bag lunches, limited meal preparation.
	H. Faculty, students, staff, must be able to use the space as a lounge, relaxing, reading, playing games.
	I. Faculty, students, staff, must be able to conduct social activities, parties, teas, etc, with food, music etc.
	J. Faculty and students must be able to use the space for private or small group discussions.
	K. Visiting lecturers must be able to use the space for a temporary office, with storage, telephoning, etc.
	L. Faculty, students, staff, must be able to use the space for layout, organization, or display of large amounts of graphic materials (either horizontally or vertically).
	M. Maintenance workers must be able to carry out their responsibilities for cleaning, upkeep, repair.

PROBLEM REQUIREMENTS continued

TYPE	REQUIREMENT
User Characteristics	A. Most personnel do not have available to them large work areas for display, organization of materials, group meetings.
	B. Many individuals enjoy eating and relaxing together and do not have space in their areas for such purposes.
	C. Some individuals are alienated by technology and react negatively to an overpowering presence of technological equipment.
	D. Most persons relate to culture and mod or avante garde styles.
	E. Many individuals are able to think creatively and perform better in a less structured, more informal setting.
	F. Many students are very conscious of faculty status and react negatively to obvious or excessive symbols of authority.
	G. Individualized, competitive study and research is becoming less popular and there is more emphasis on group thinking and production.
	H. Personnel responsible for maintenance have their own important functions which must be taken into consideration.

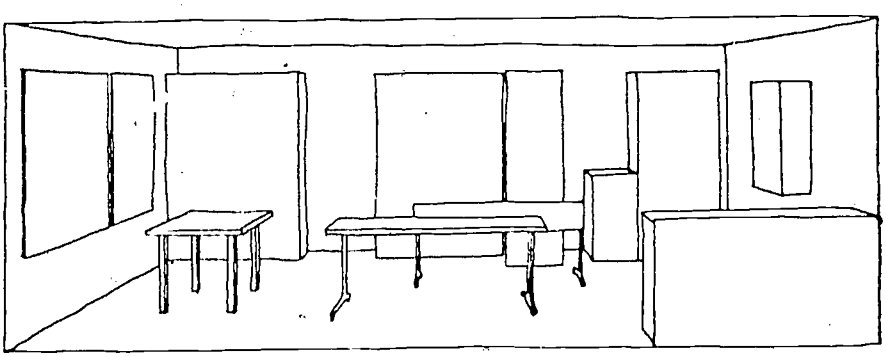
Appendix H-3 Solution Drawings

This presents the 27 solution drawings generated in the test sessions, as redrawn for presentation to the solution evaluators, organized by test problem, strategy, and subject.



(NO DOOR OR WINDOW SHOWN)

SCALE 1/8" = 1' 16'X27' EST. 432 SQ. FT.



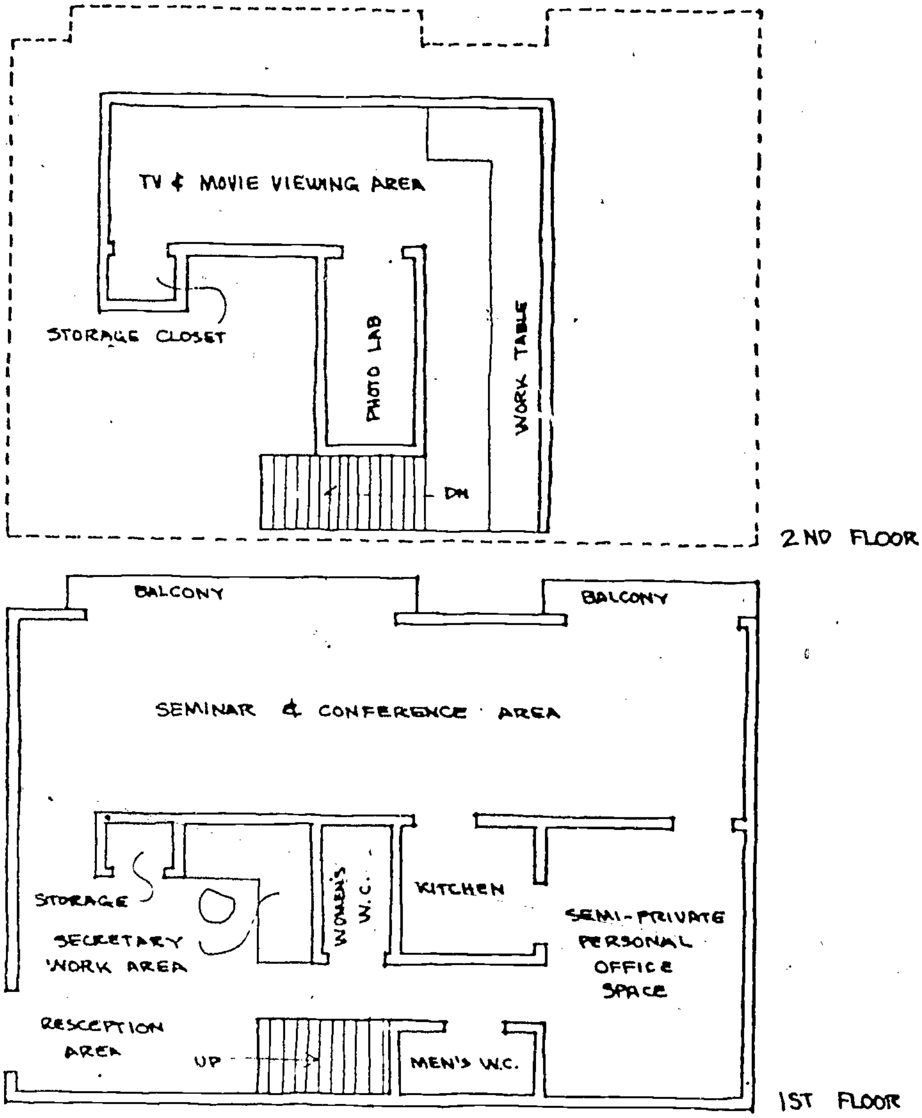
NO GRAPHICS

PRIMARY AREA

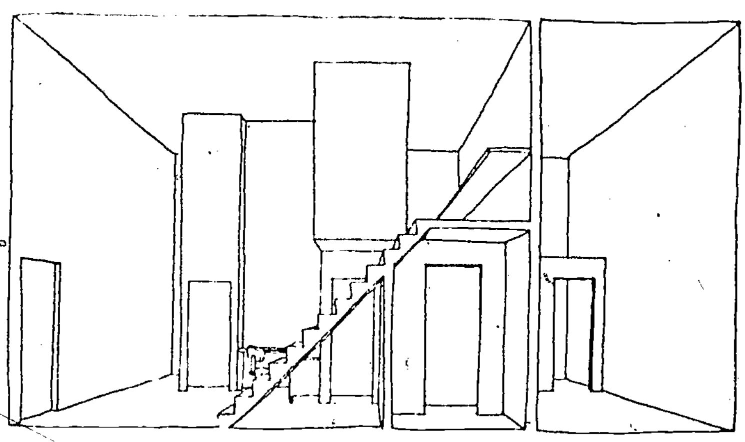
SECRETARIAL CHAIR
SECRETARIAL DESK
FILE CABINET
BOOK SHELVES
DRAFTING TABLE

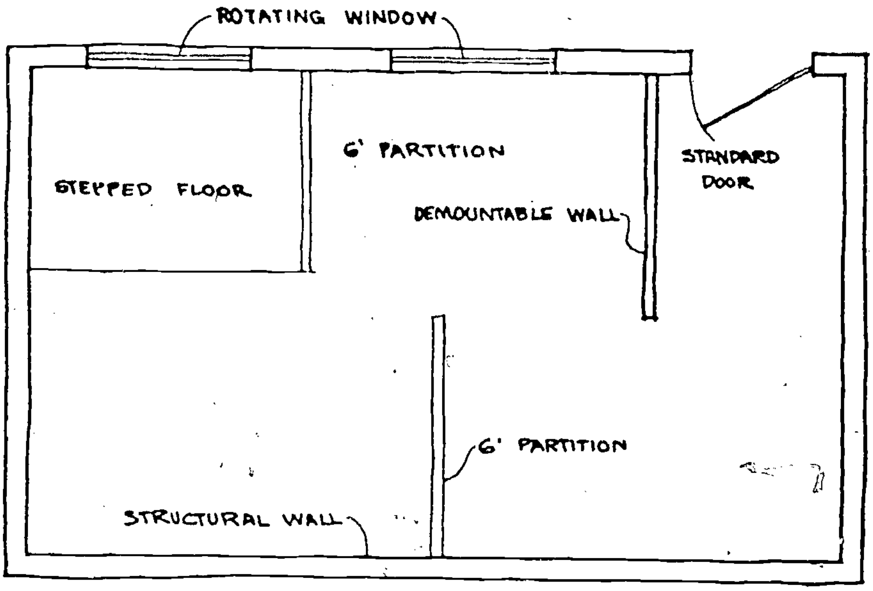
CONFERENCE AREA

ARM CHAIRS
DIRECTOR'S CHAIR
CONFERENCE TABLE
STORAGE SHELF
EQUIPMENT CLOSET
FREE STANDING PARTITION
TACKBOARD

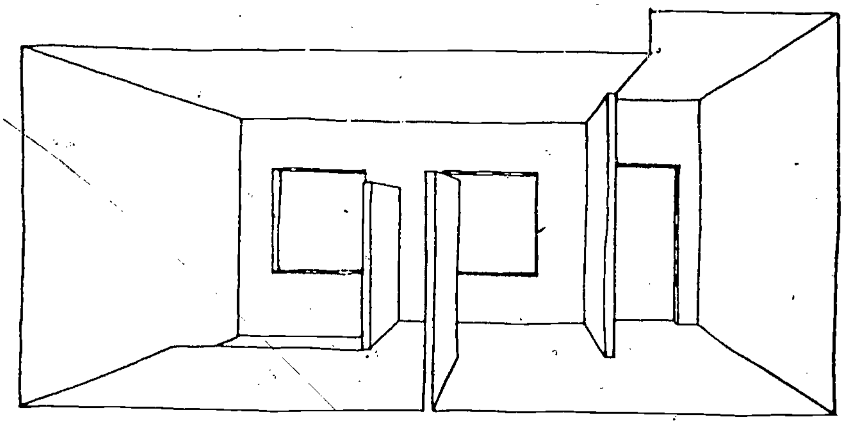


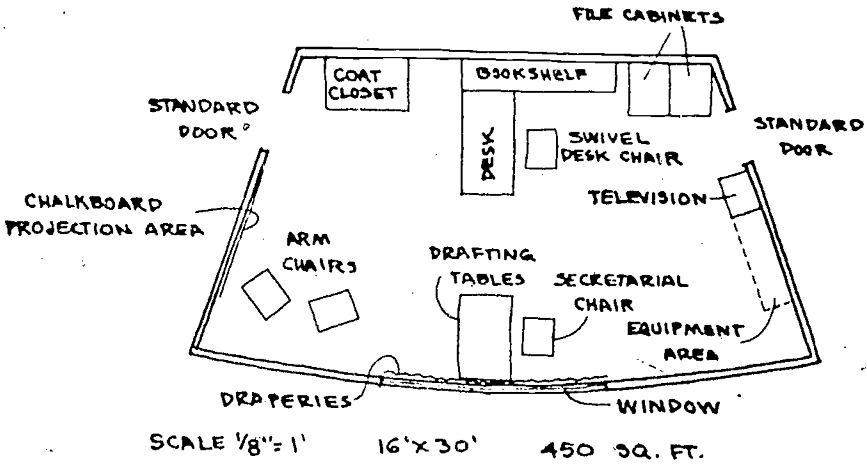
SCALE 1/8" = 1' 24'X36 1ST. FLOOR EST. 360 SQ. FT. 2 FLOORS

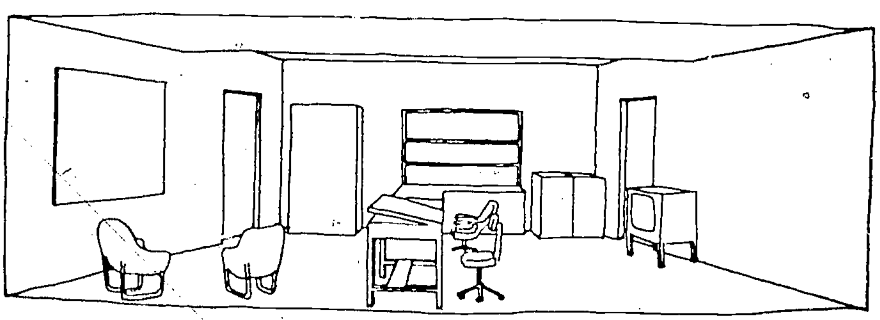


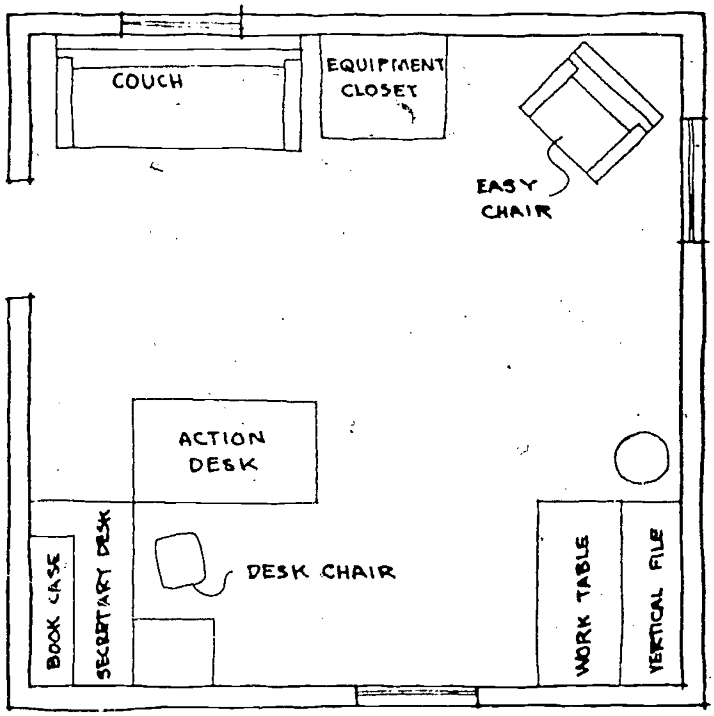


SCALE 1/4" = 1' 12' X 20' 240 SQ. FT.

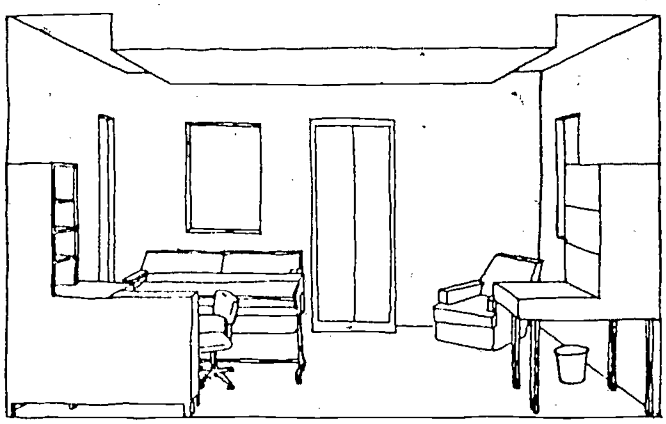


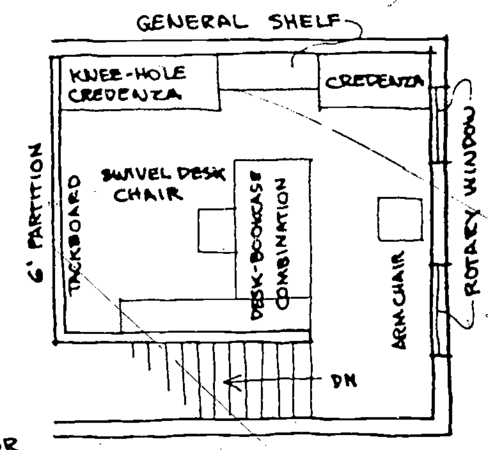

FILE CABINETS
COAT CLOSET
BOOKSHELF
STANDARD DOOR
DESK
SWIVEL DESK CHAIR
STANDARD DOOR
TELEVISION
CHALKBOARD PROJECTION AREA
ARM CHAIRS
DRAFTING TABLES
SECRETARIAL CHAIR
EQUIPMENT AREA
DRAPERIES
WINDOW
SCALE 1/8" = 1'
16' x 30'
450 SQ. FT.



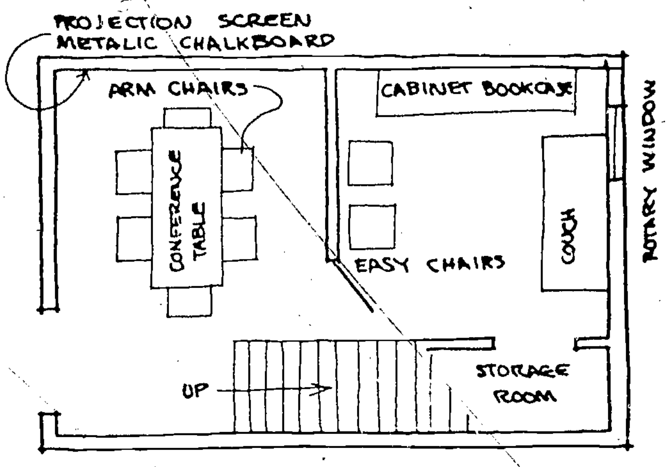


SCALE 1/4" = 1' 16' x 16' 256 SQ. FT.



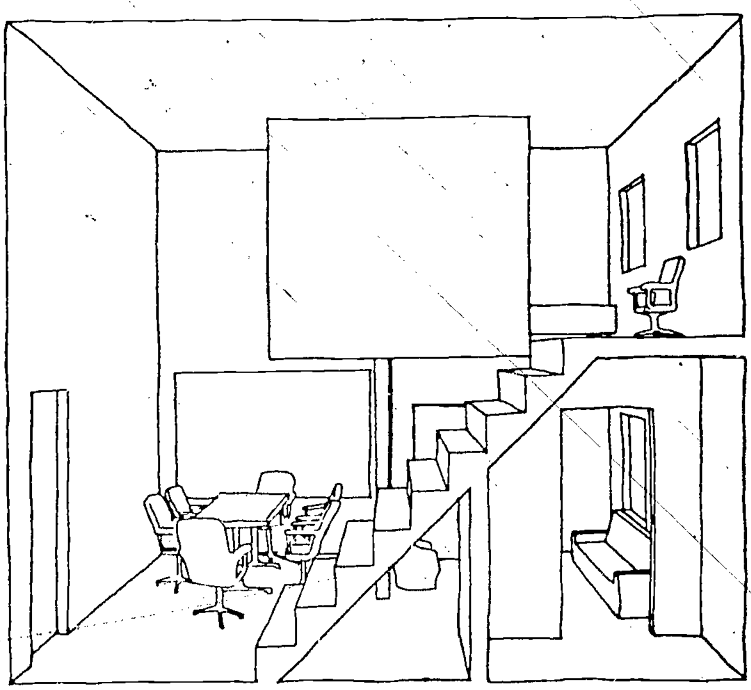


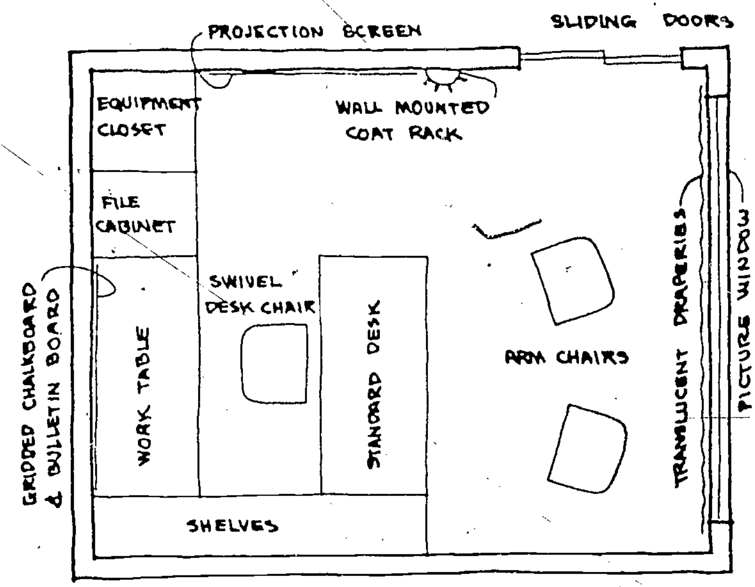
2ND FLOOR



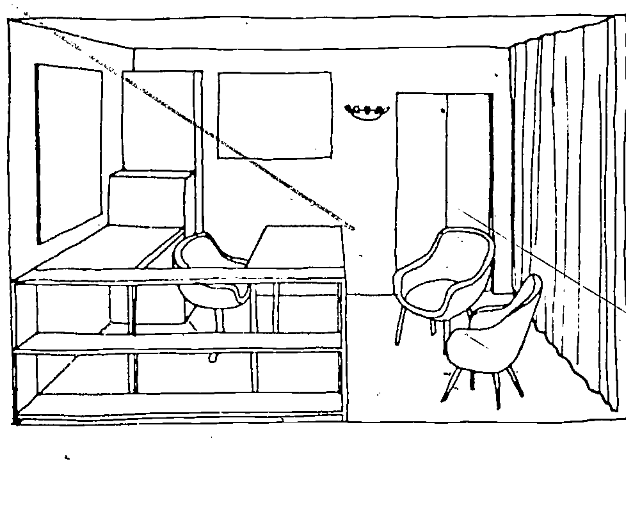
1ST FLOOR

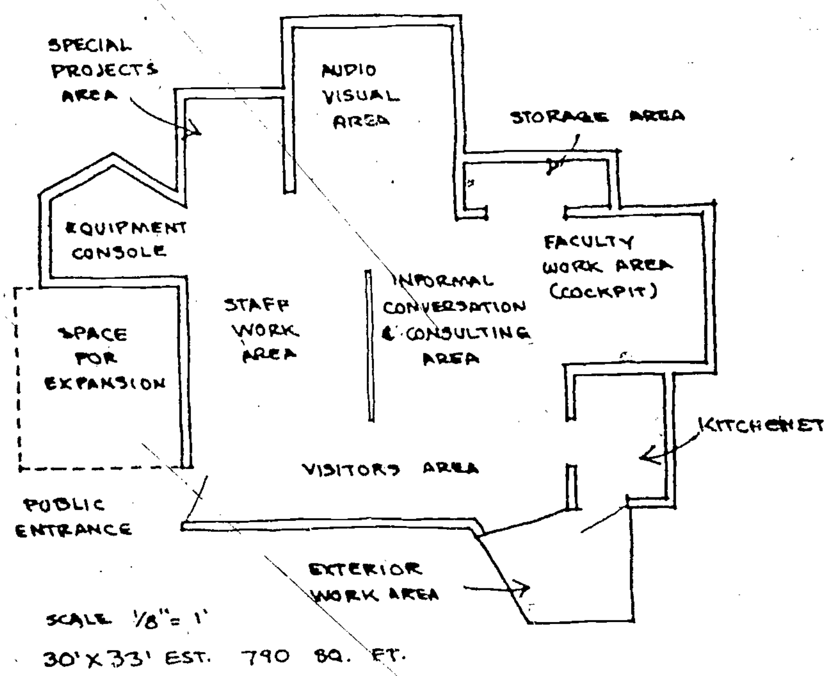
SCALE 3/16" 12'X12' 12'X18' 360 SQ. FT. 2 FLOORS

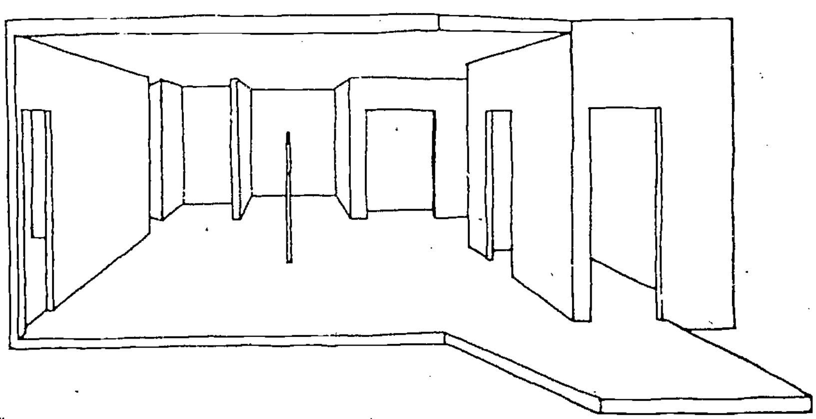


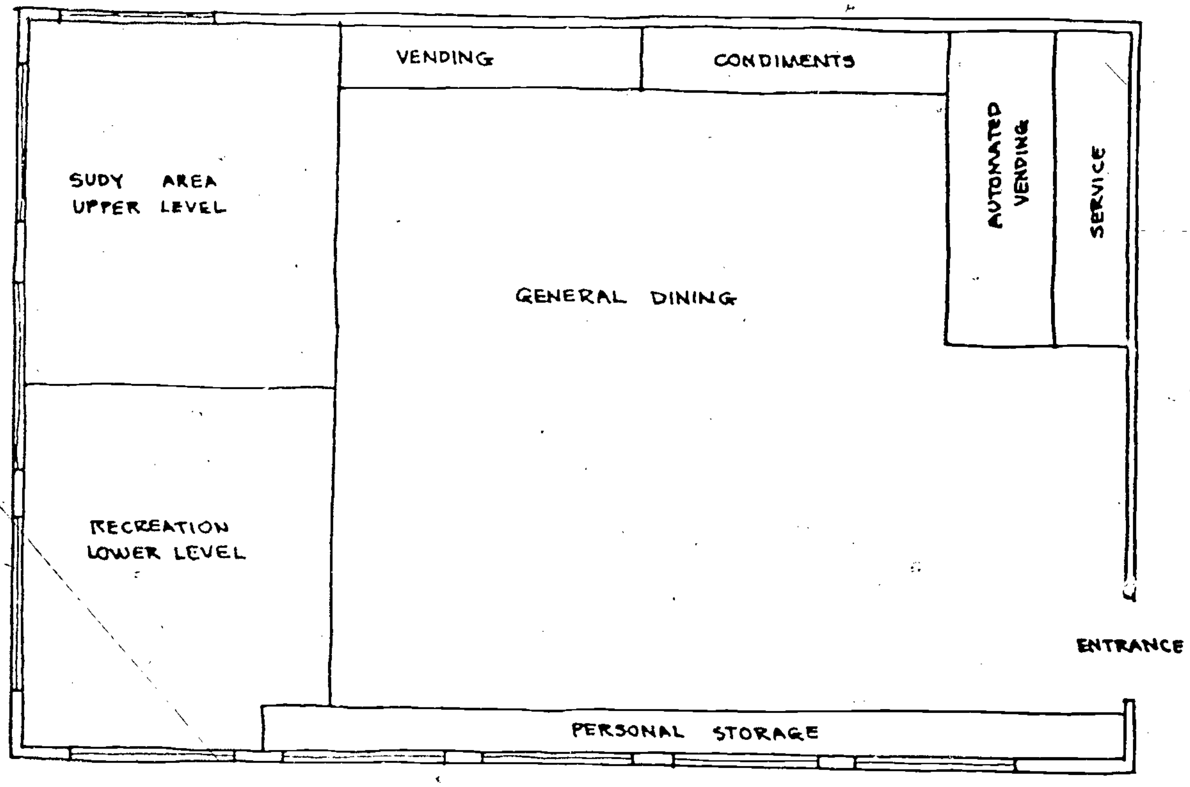


SCALE 1/4" = 1'   12' X 15'   180 SQ. FT.

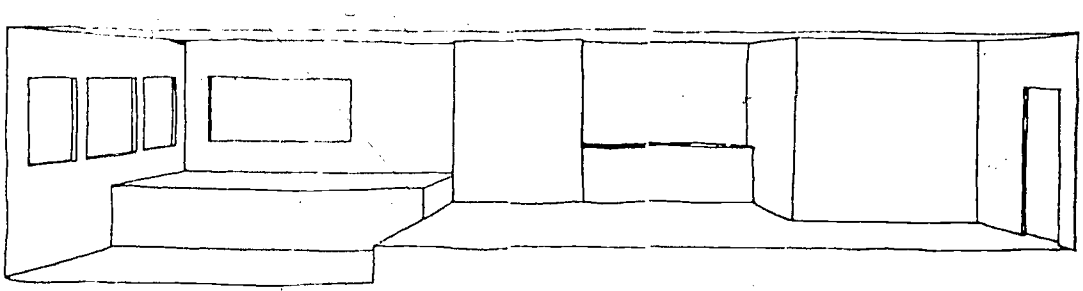


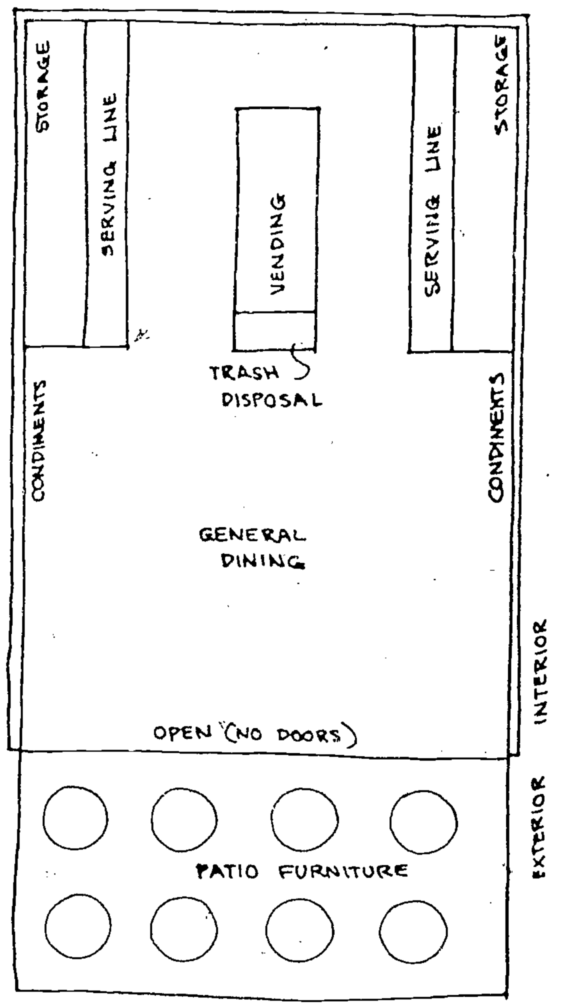

SPECIAL PROJECTS AREA
AUDIO VISUAL AREA
STORAGE AREA
EQUIPMENT CONSOLE
FACULTY WORK AREA (COCKPIT)
INFORMAL CONVERSATION & CONSULTING AREA
STAFF WORK AREA
SPACE FOR EXPANSION
KITCHENET
VISITORS AREA
PUBLIC ENTRANCE
EXTERIOR WORK AREA
SCALE 1/8" = 1'
30' X 33' EST. 790 SQ. FT.



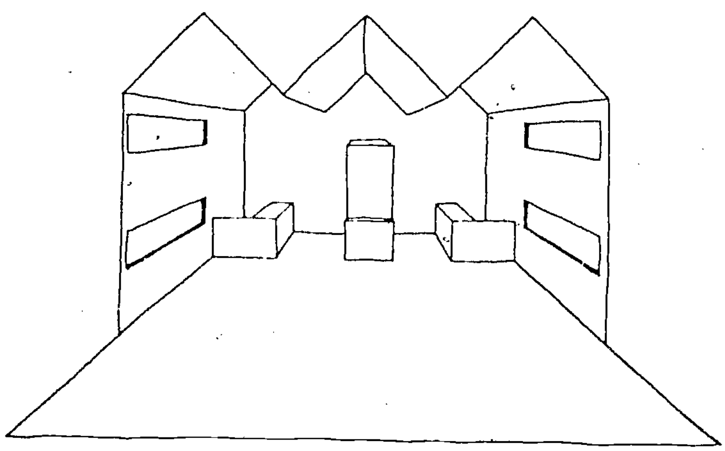


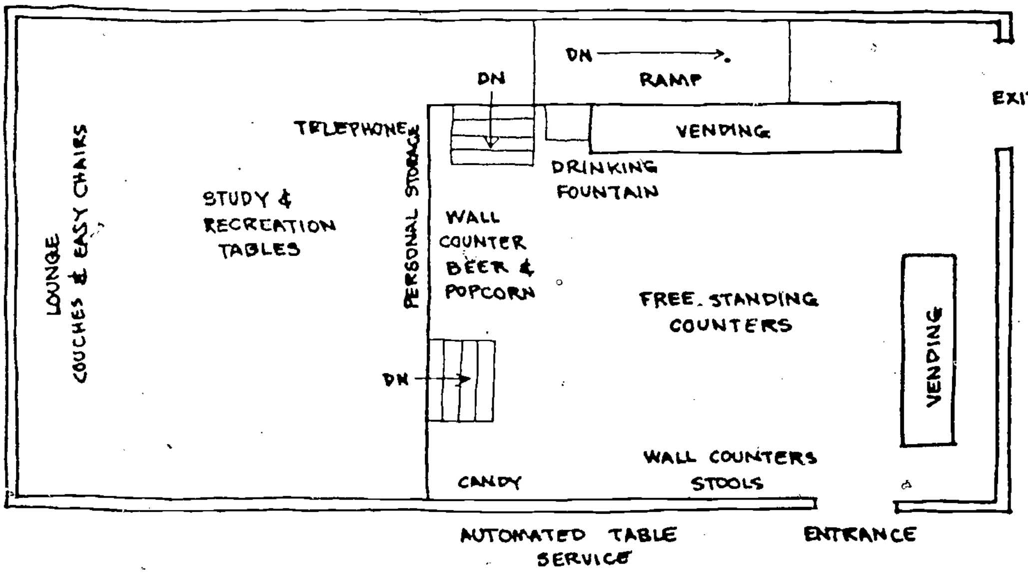
SCALE 3/32" = 1' 48' × 72' 3456 SQ. FT.



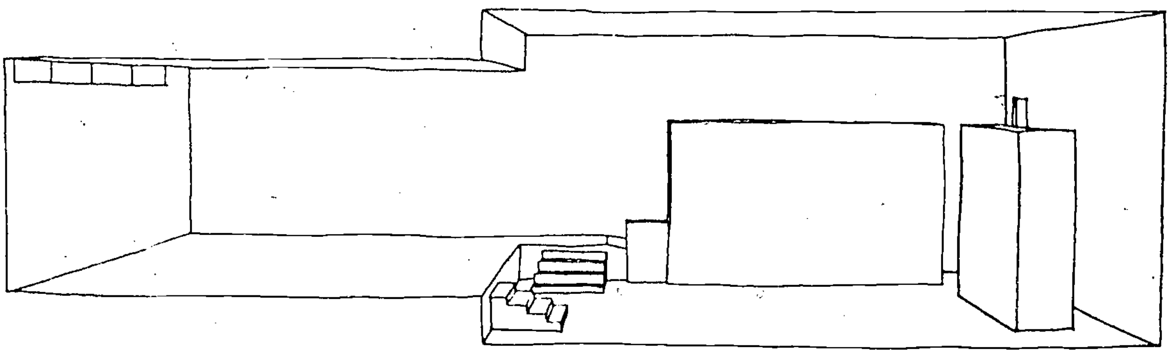


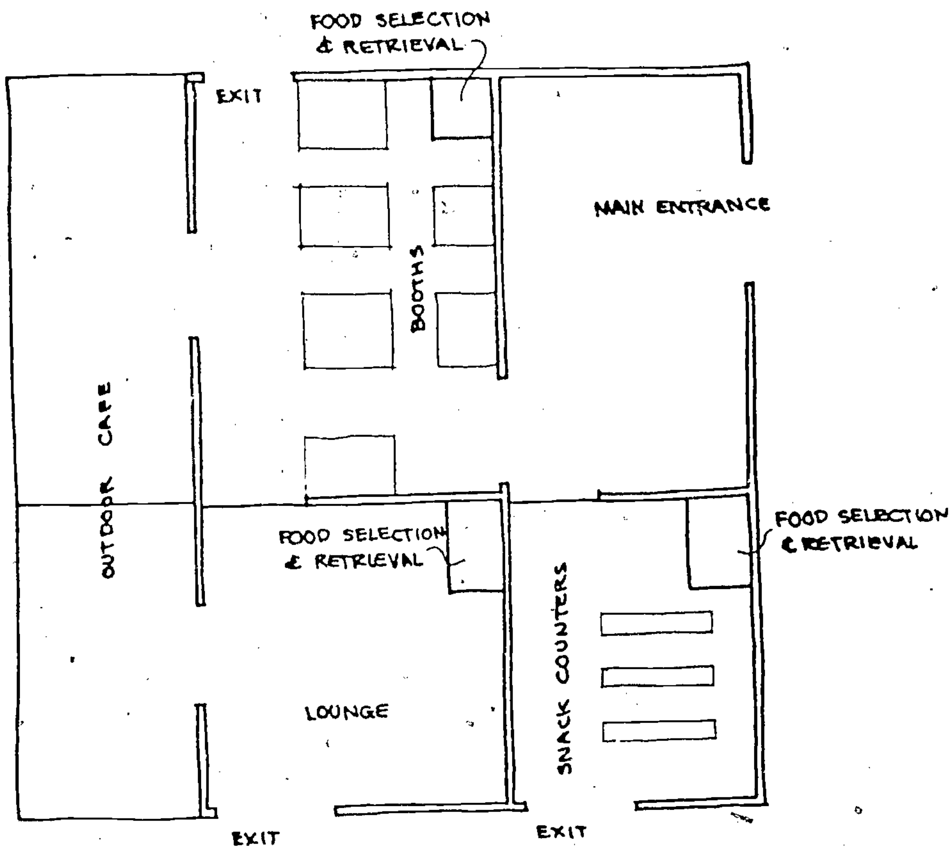
SCALE 1/8" = 1' 48' X 24' 1152 SQ. FT.



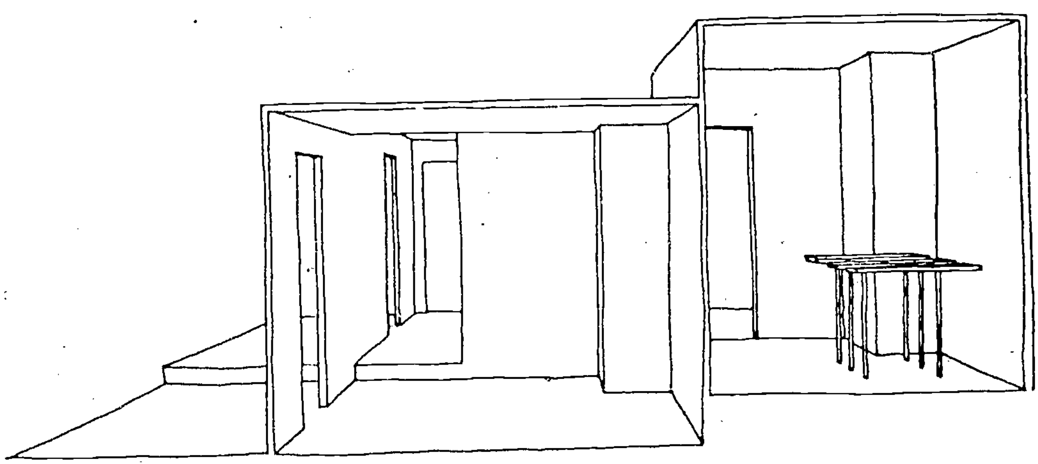


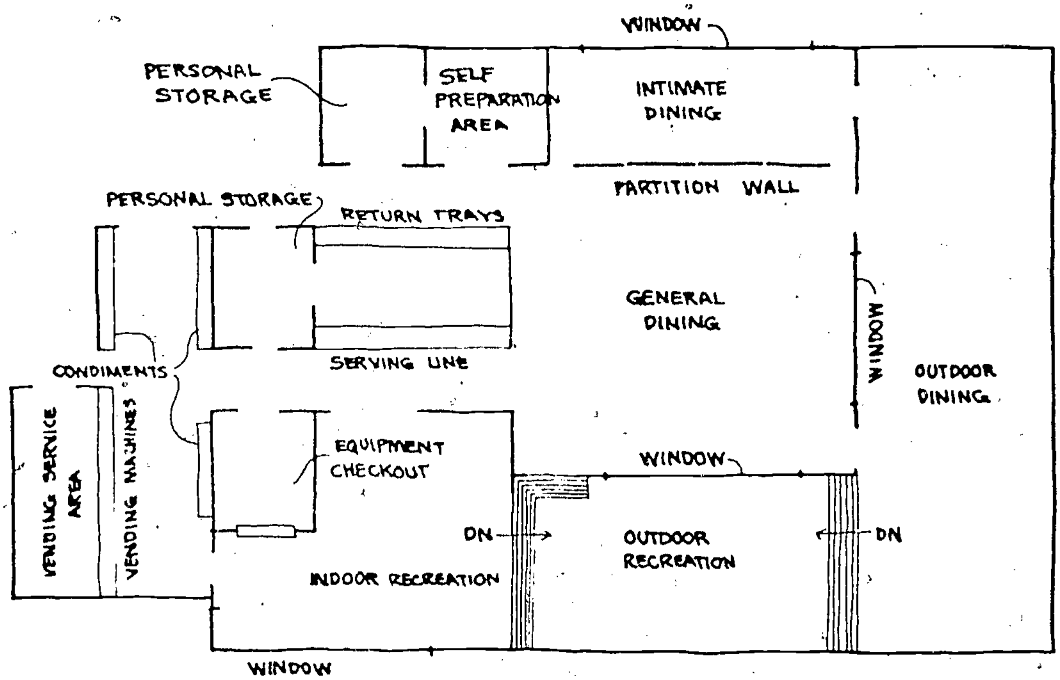
SCALE 1/8" = 1' 24' x 48' EST. 1152 SQ. FT.



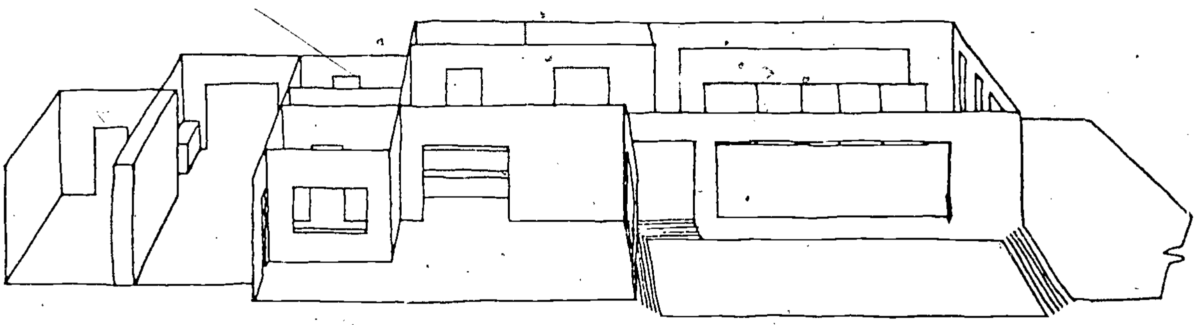


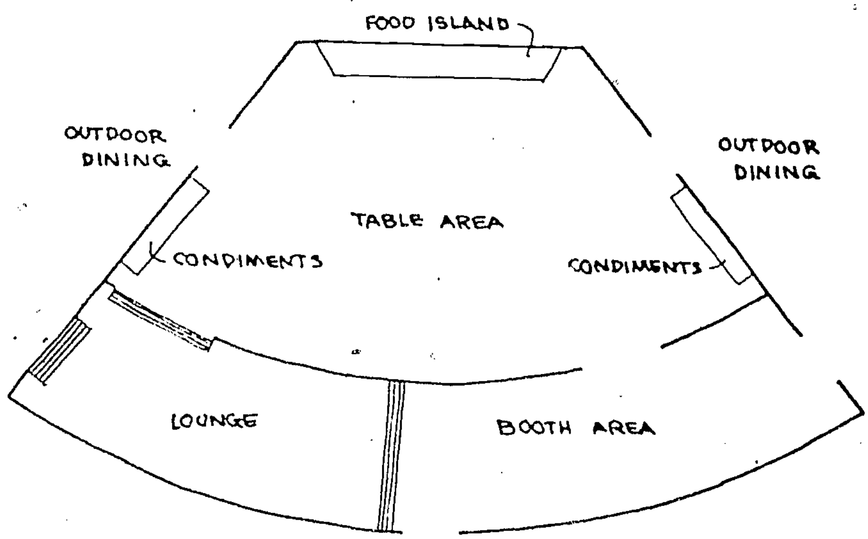
SCALE 3/16" = 1' 24' x 24' 576 SQ. FT.



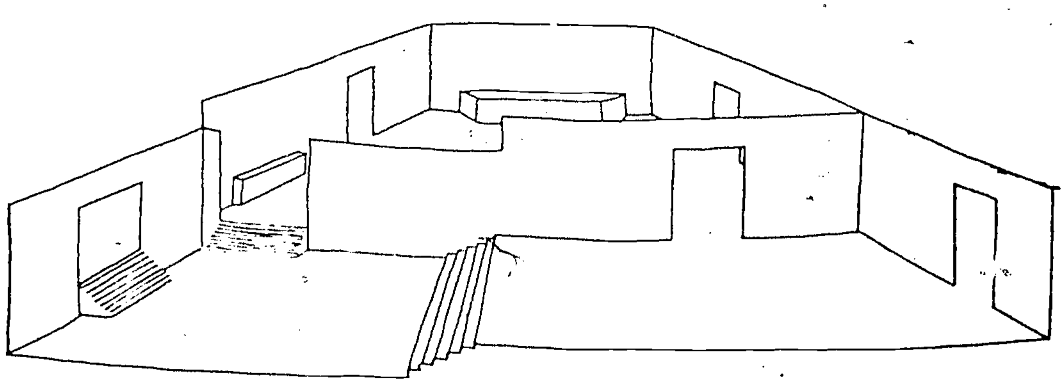


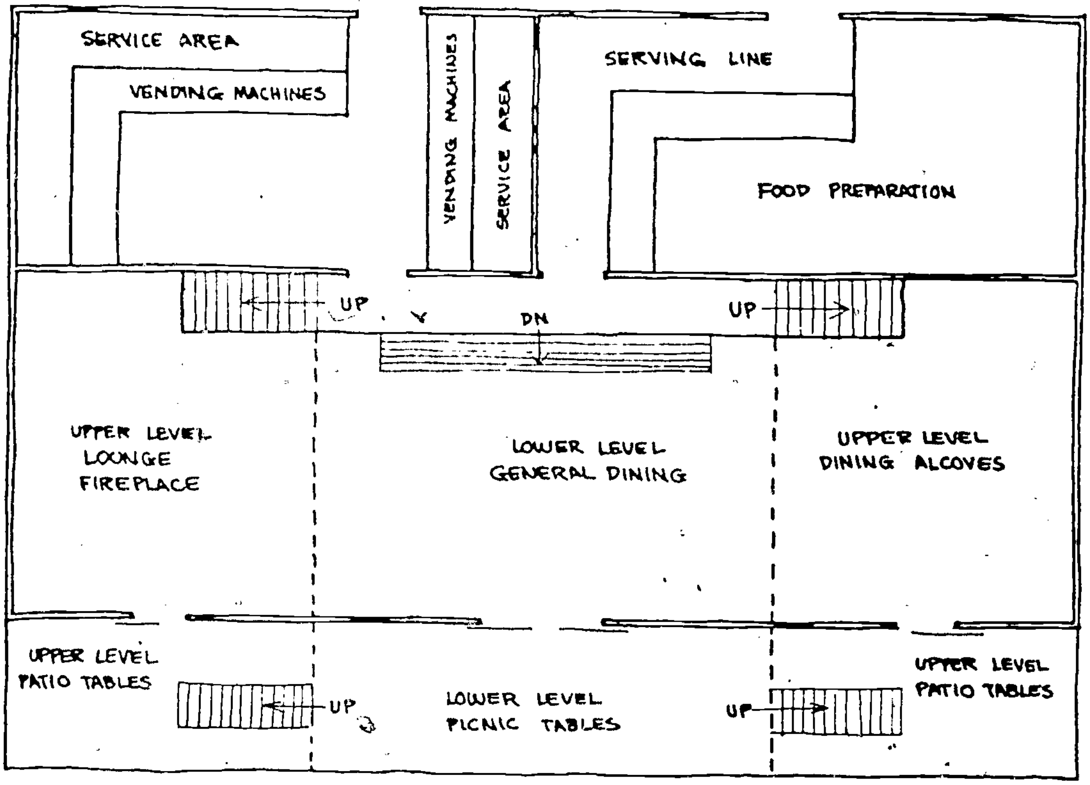
SCALE 3/8" = 10' 100' X 170' 17000 SQ. FT.



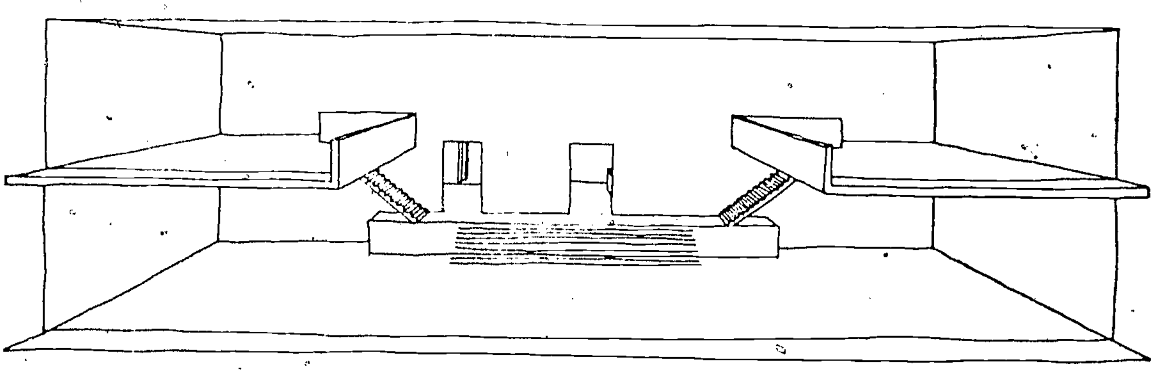


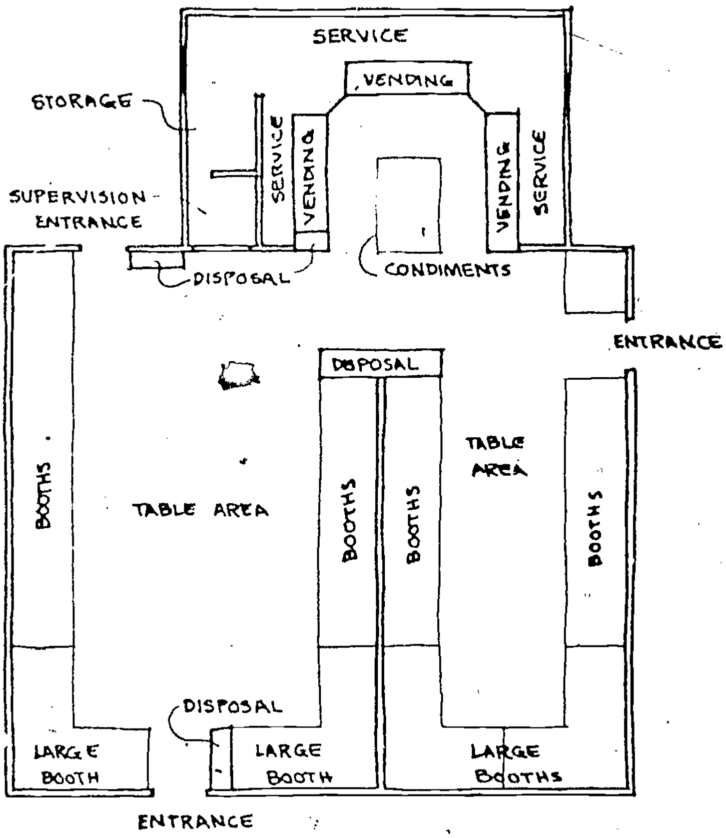
NO SCALE 48' x 84' EST. 4032 SQ. FT.



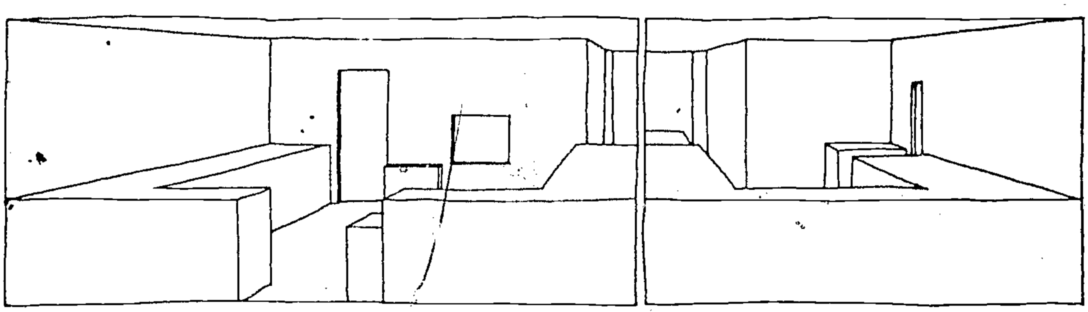


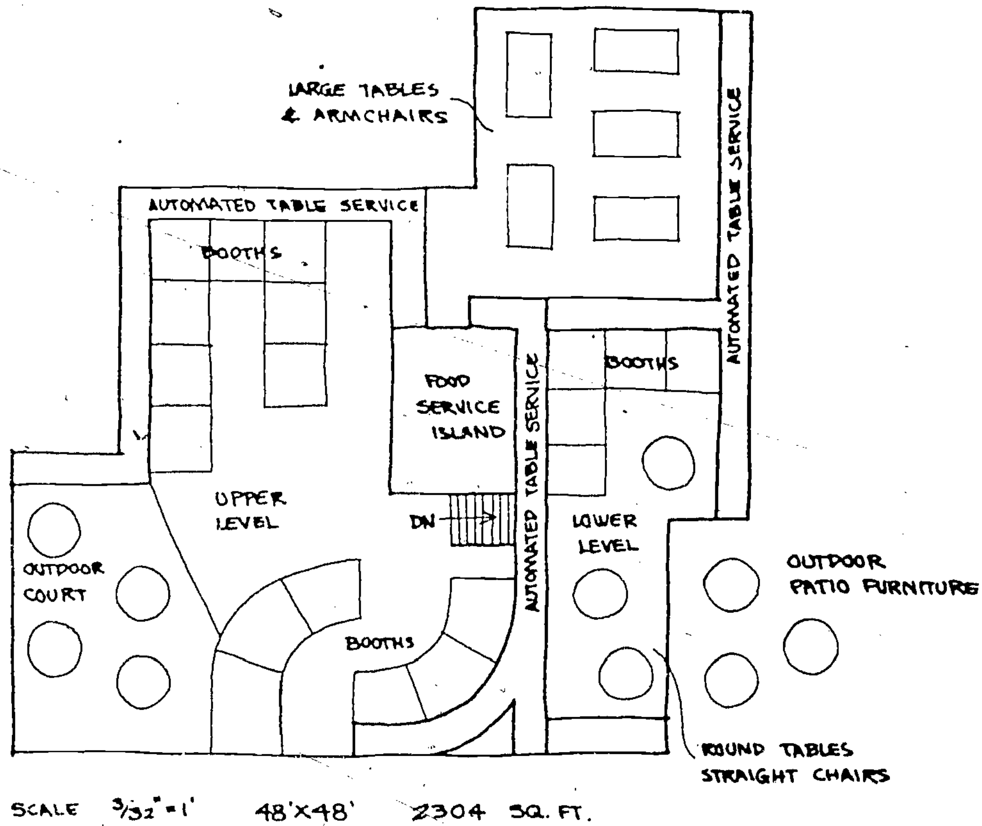
SCALE 3/32" = 1'   56' x 70' 1ST. FLOOR EST.   5360 SQ. FT.

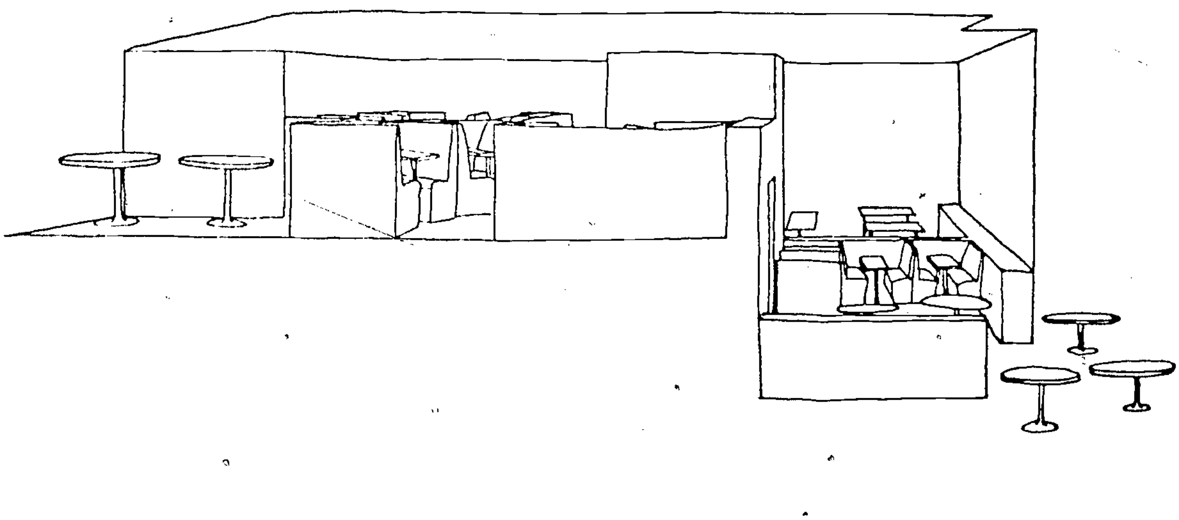


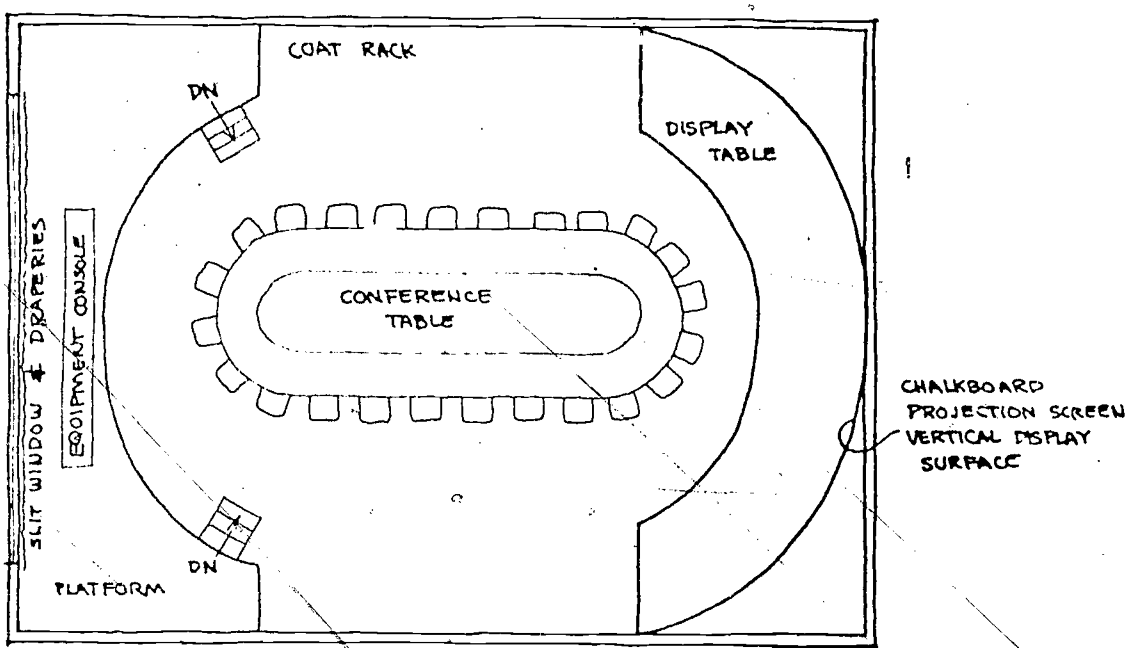


SCALE 3/32" = 1' 50' x 40' EST: 2000 SQ. FT.

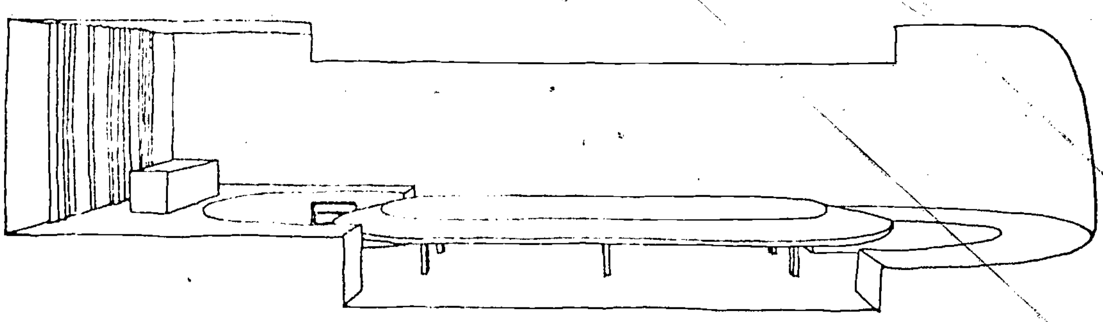


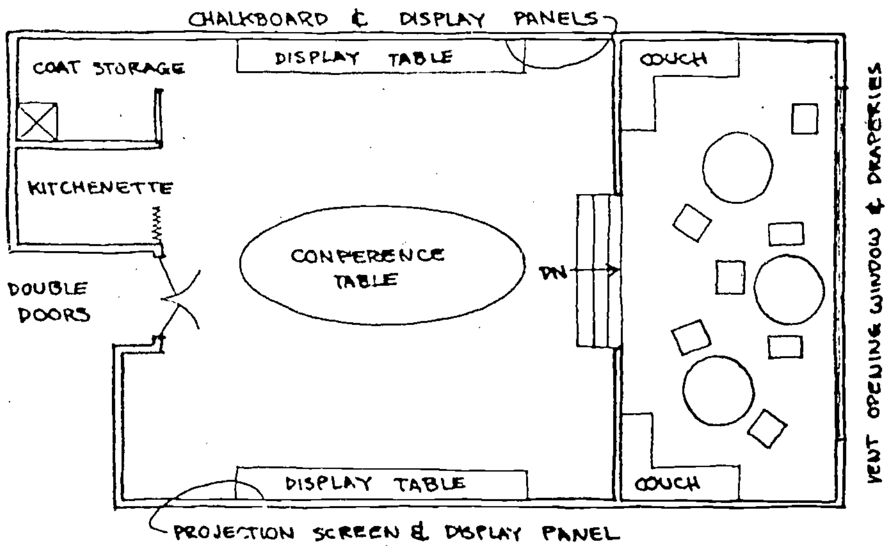

LARGE TABLES
& ARMCHAIRS
AUTOMATED TABLE SERVICE
BOOTHS
FOOD
SERVICE
ISLAND
AUTOMATED TABLE SERVICE
BOOTHS
AUTOMATED TABLE SERVICE
UPPER
LEVEL
DN
LOWER
LEVEL
OUTDOOR
COURT
BOOTHS
OUTDOOR
PATIO FURNITURE
ROUND TABLES
STRAIGHT CHAIRS
SCALE 3/32" = 1' 48'X48' 2304 SQ. FT.



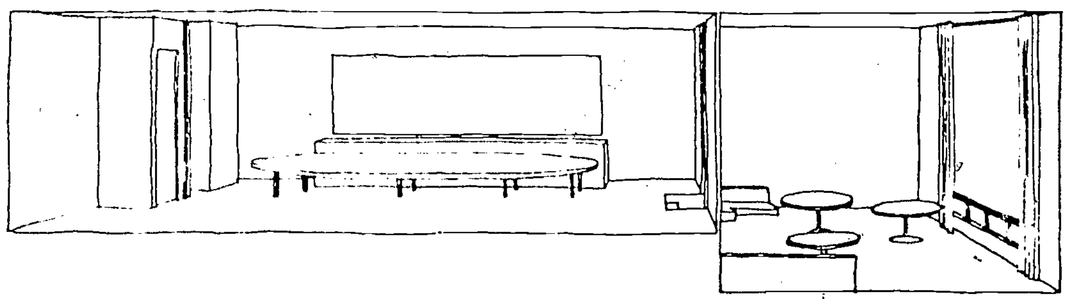


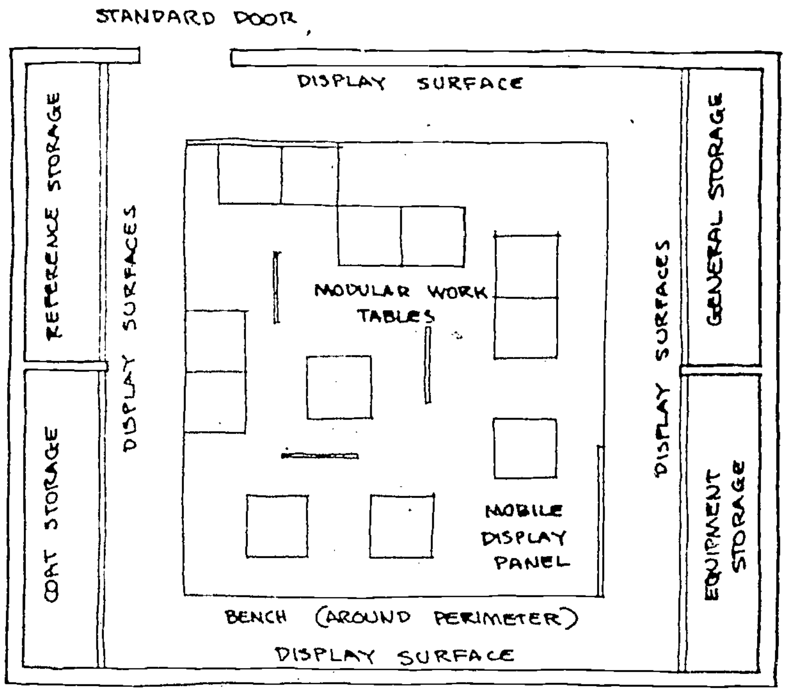
SCALE 1/8"=1' 30'x 42' EST. 1260 SQ. FT.



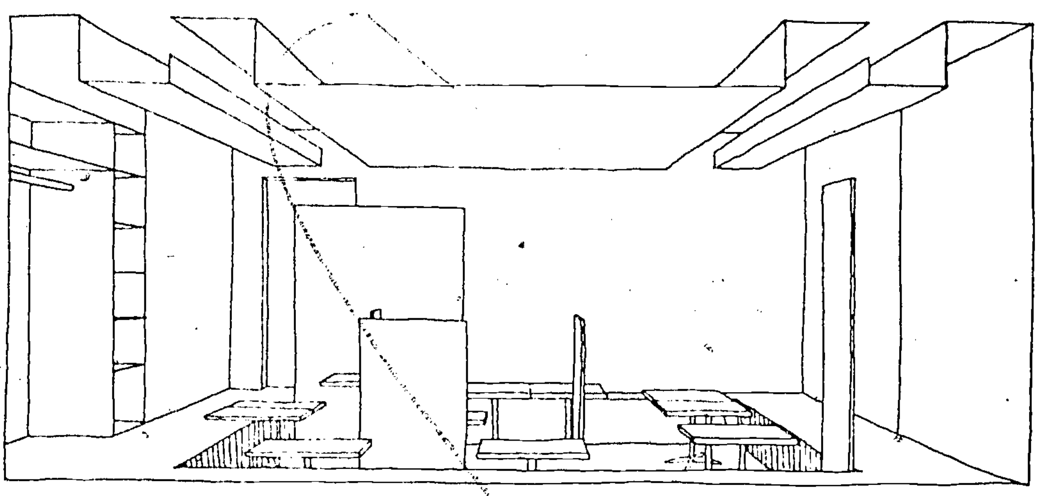


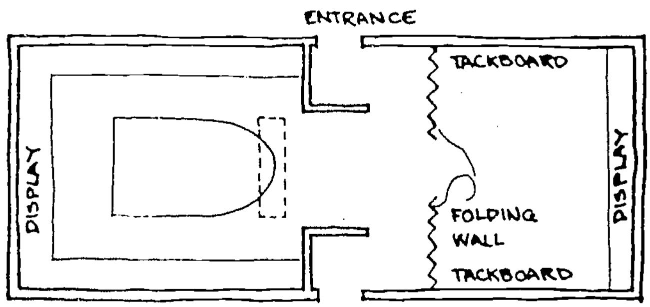
SCALE 3/32" = 1' 30'x 54' EST. 1620 SQ. FT.



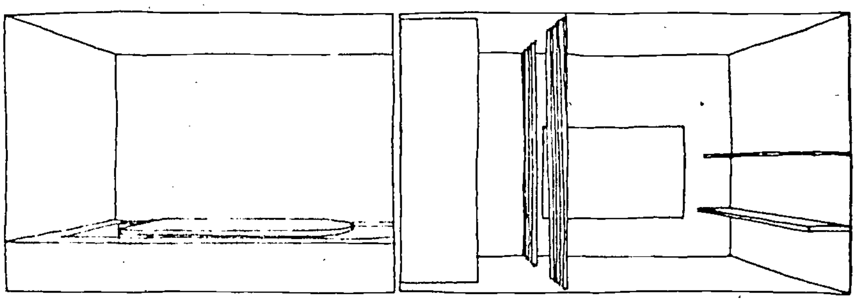


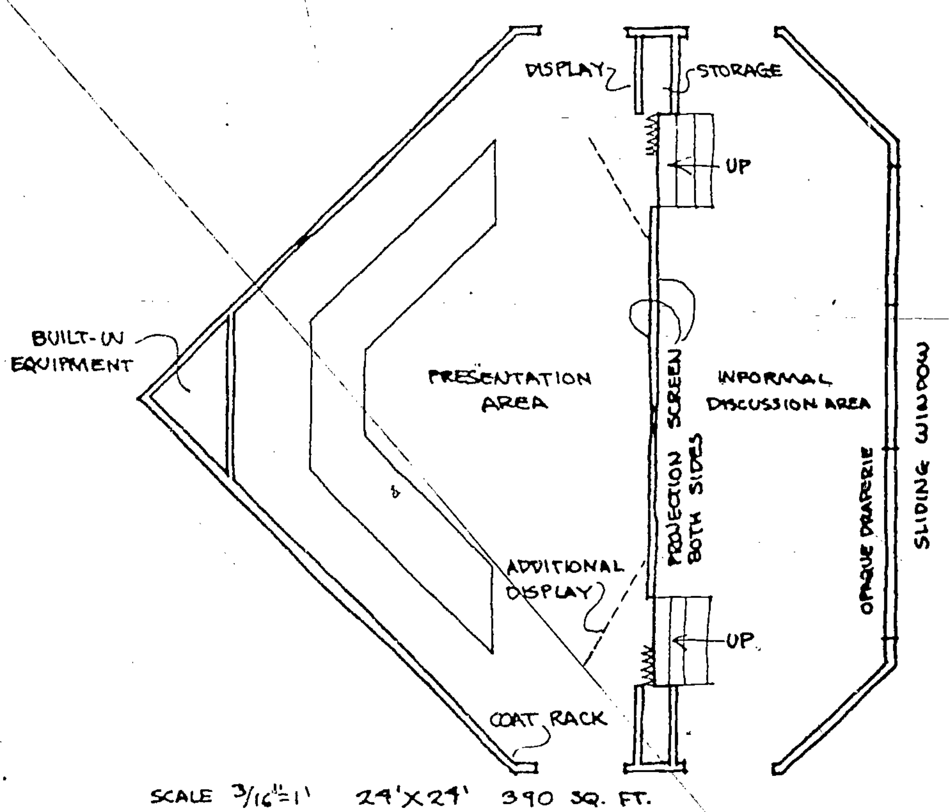
SCALE 3/16" = 1' 20'X24' EST. 450 SQ. FT.

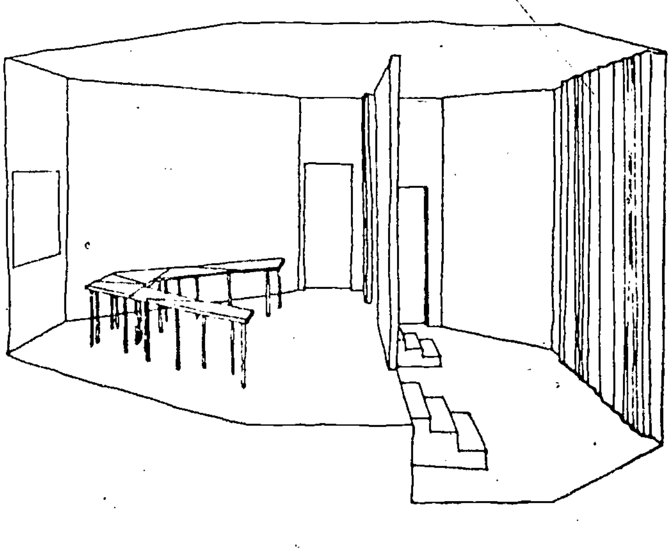


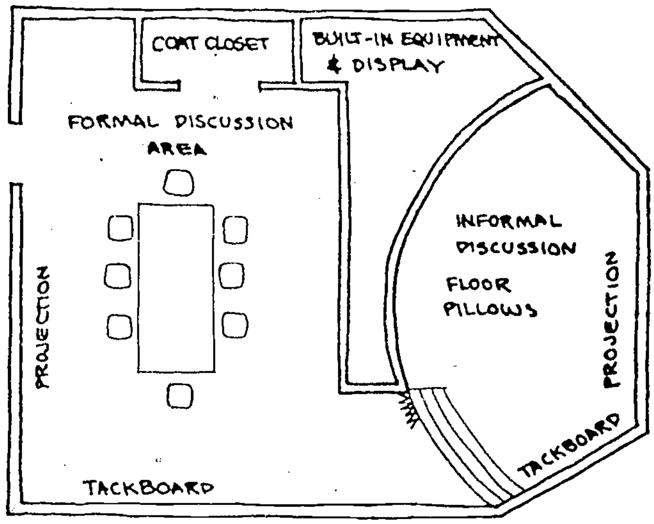


SCALE 1/8"=1' 12' X 30' 360 SQ. FT.

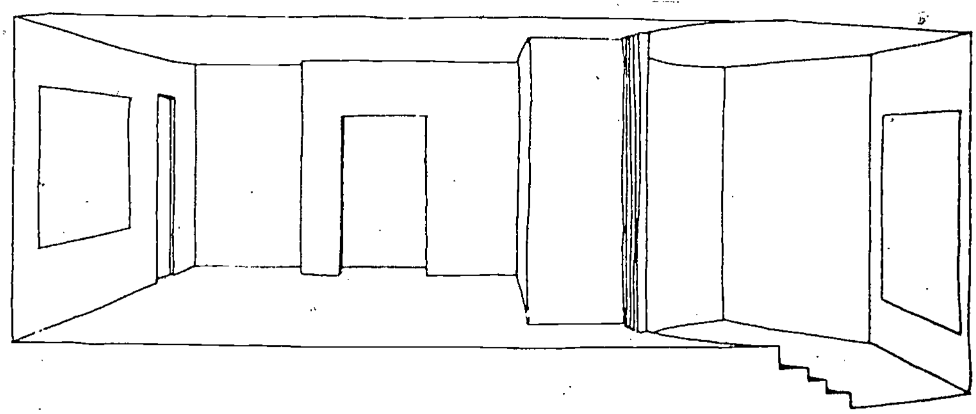


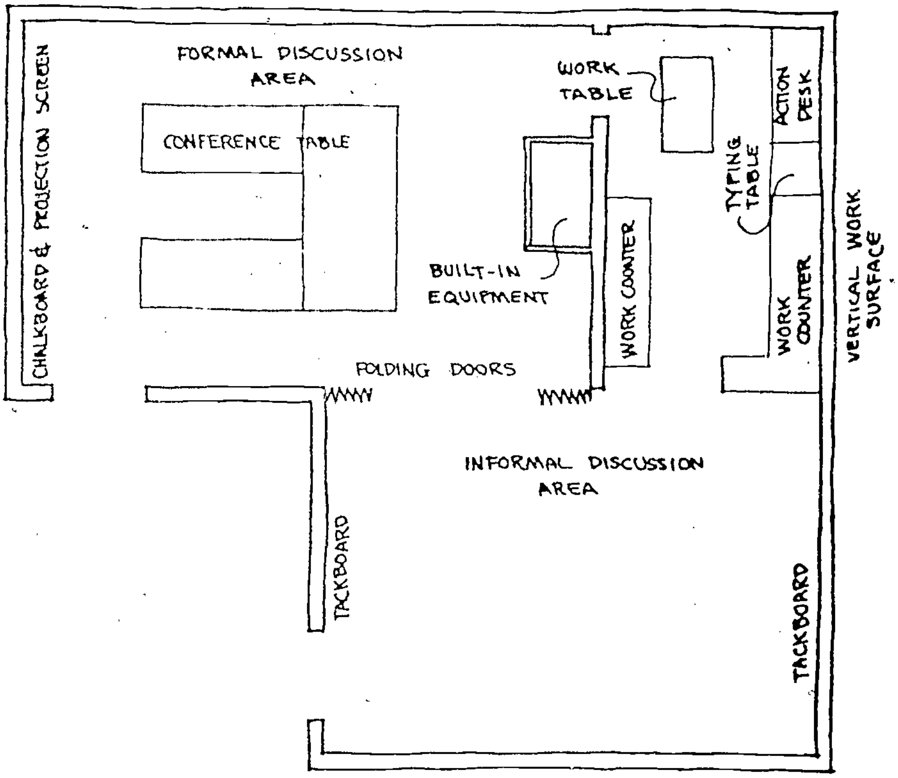

DISPLAY
STORAGE
UP
BUILT-IN
EQUIPMENT
PRESENTATION
AREA
PROJECTION SCREEN
BOTH SIDES
INFORMAL
DISCUSSION AREA
OPAQUE DRAPERIE
SLIDING WINDOW
ADDITIONAL
DISPLAY
UP
COAT RACK
SCALE 3/16"=1' 24'X24' 390 SQ. FT.



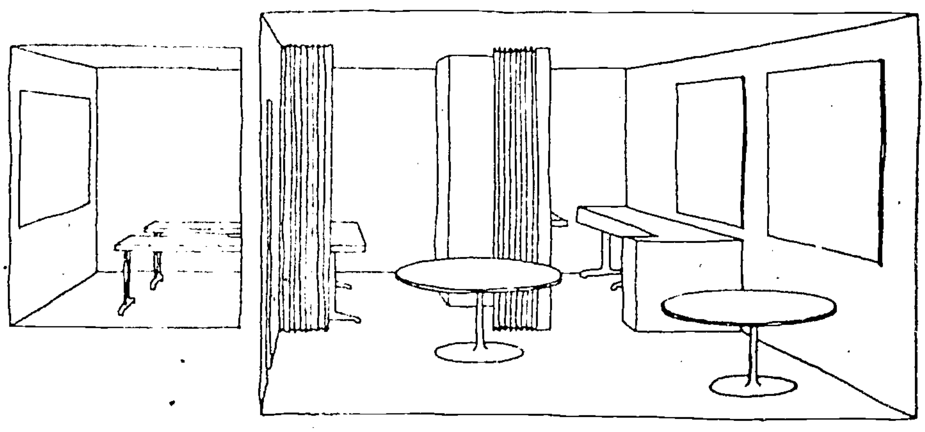


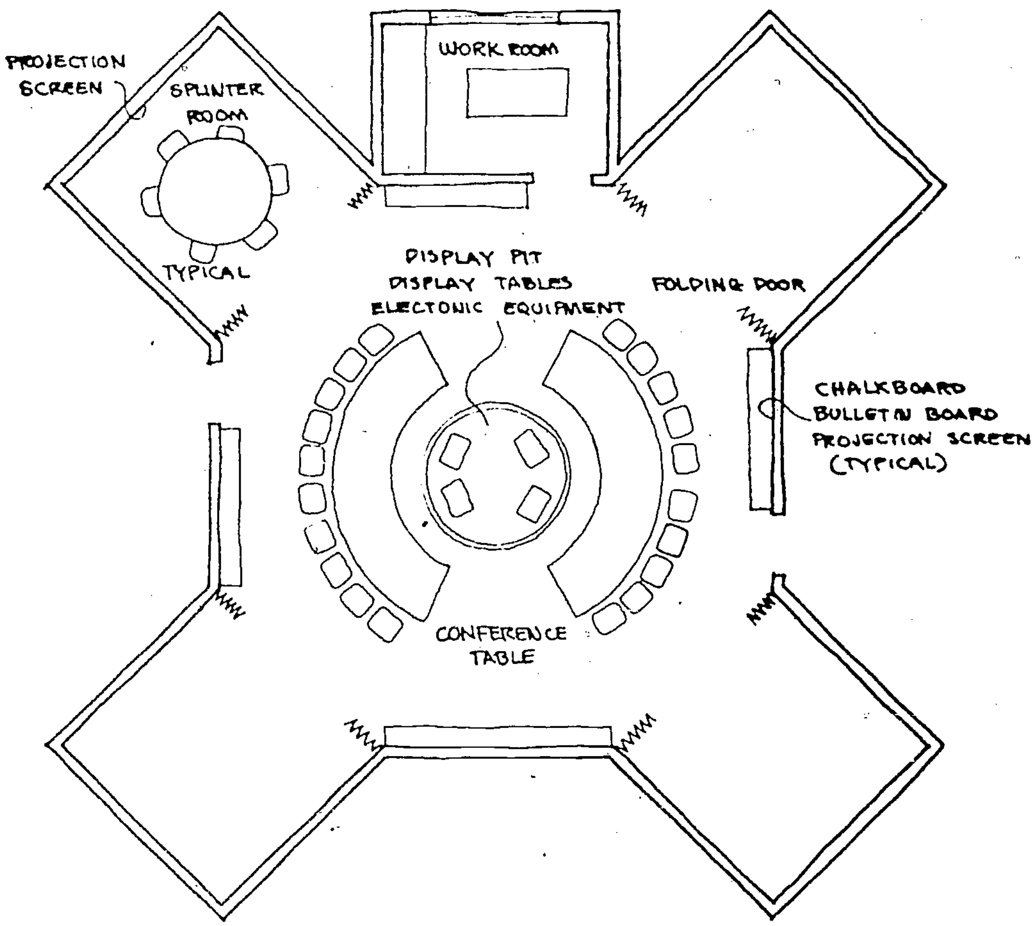
SCALE 1/8"=1' 29'×30' EST. 710 SQ. FT.



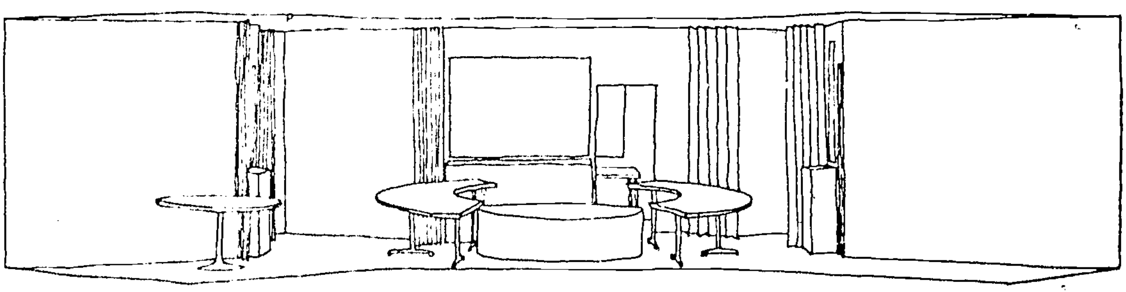


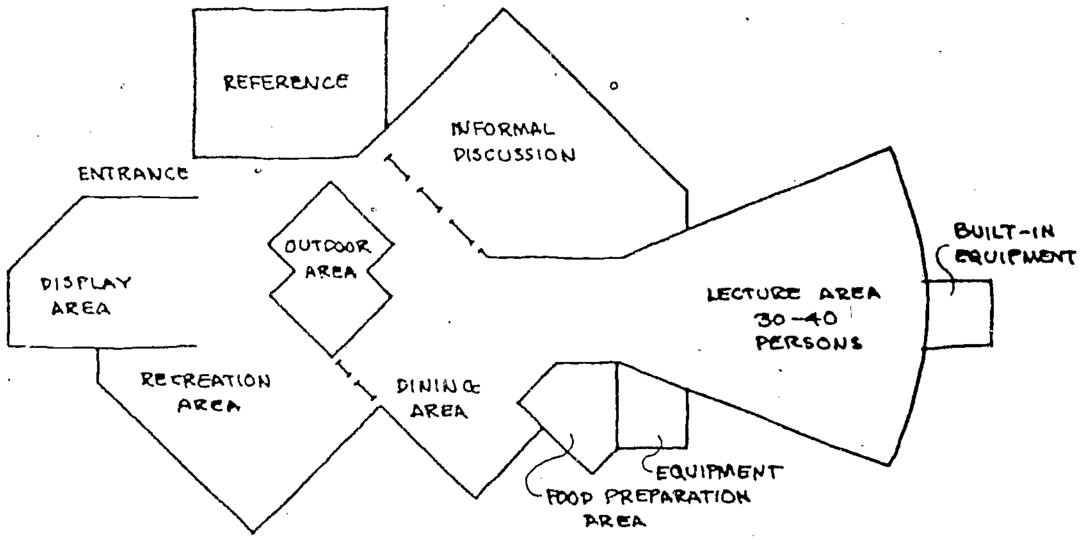
SCALE 3/16" = 1'   24' X 26' EST.   624 SQ. FT.



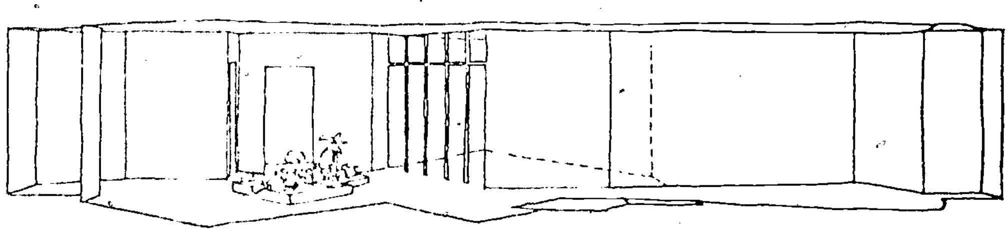


SCALE 1/8" = 1' 44'x44' EST. 1130 SQ. FT.





NO SCALE 48'x90' 4000 SQ. FT.



Appendix H-4 Solution Specification Examples

This provides 9 examples of the solution specification lists generated from the information cards selected by the subjects, as provided to the solution evaluators. The examples were selected from the overall set of 27 solution specification sheets to indicate the most comprehensive listings in each strategy group for a given problem, and some listings in each group were much briefer. However, these illustrations are included to demonstrate the complexity of description possible using the information cards rather than for comparing solutions.

Problem I, 5-Step, Subject #3

Solution Specifications

SEATING
- Desk Chair (swivel)
- Bench

WORK SURFACES
- Action Desk (built-in electronic equipment)
- Credenza
- Typing Table
- Work Counter
- Chalkboard
- Projection Screen

STORAGE
- Book Shelf
- General Shelf
- Vertical File
- File Bin
- File Cabinet
- File Rack
- Equipment Stand
- Equipment Cabinet
- Equipment Closet
- Counter

MAJOR EQUIPMENT
- Type Recorder
- Radio
- Standard Telephone
- Computer I&O
- Desk Calculator
- Typewriter
- Television Set
- Videotape Recorder
- Microfilm Camera
- Microfilm Viewer
- Xerox Machine
- Drinking Fountain
- Hand Sink
- Work Sink
- Urinal
- Toilet

MINOR EQUIPMENT
- Ashtray
- Calender
- Clock
- Pencil Sharpener
- Stapler
- Tray
- Wastebasket
- Dishes
- Glasses
- Pots & Pans
- Coffee Maker
- Hot Plate
- Refrigerator

LIGHTING
- Tensor Lamp
- Drawing Lamp
- Spot Light
- Ceiling, Fluorescent
- Rheostat

SERVICES
- Cool Air
- Fresh Air
- Hot Air
- Exhaust
- Chilled Water

MATERIALS
- Concrete
- Glass
- Plaster
- Brick
- Cork
- Leather
- Bamboo
- Wood

Enclosure Surfaces: white, natural finish

Problem I, 10-Step, Subject #1

Solution Specification

SEATING
  Desk Chair
    (high back, swivel)
  rm Chair
  Drafting Stool
  Art Chair
    (brown leather)
  Easy Chair
    (reclining, brown leather)
  Counch
    (brown leather)

WORK SURFACES
  Action Desk
  2-person Desk
  Credenza
  Typing Table
  Work Table
  Work Counter
  Chalkboard
    (gridded)
  Tackboard
  Projection Screen
  Card Rack
  Control Chart
  Storage
  Book Shelf
  Pigeon Holes
  File Cabinet
  Equipment Cabinet
  Counter
  Cabinet
  Coat Closet

All Furniture
Surfaces:
Woodgrained
Natural
Texture

All Storage:
Built-in

MAJOR EQUIPMENT
  Tape Recorder
  Computer I & O
    (graphic)
  Radio
  Push-Button Phone
  Dictaphone
  Typewriter
  Desk Calculator
  Opaque Projector
  Film Projector
  Xerox Machine
  Hand Sink
  Toilet
  Shower
  Air Conditioner

MINOR EQUIPMENT
  Art Object
  Ash Tray
  Calendar
  Clock
  Mirror
  Pencil Sharpener
  Stapler
  Waste Basket
  Coffee Cups
  Dishes
  Glasses
  Pots & Pans
  Coffee Pot
  Hot Plate
  Refrigerator
  Fire Place

LIGHTING
  Desk Lamp
  Tensor Lamp
  Drawing Lamp
  Ceiling
    (incandescent)
  Theostat

ENCLOSURE
  Clerestory Window
  Vent-Opening Window
  Thermopane
  Draperies
    (translucent)
  Sunshields
  Standard Door
  6' Partition
  Demountable Wall
  Structural Wall
  Walls, primary, white
    grey, brown, orange,
    woven
  Stepped Floor
  Wall-to-Wall Carpet
  Multi-Level Ceiling

SERVICES
  Cool Air
  Fresh Air
  Hot Air

All Equipment Surfaces:
flat finish, painted

Problem I, 15-Step, Subject #2

Solution Specifications

SEATING
- Desk Chair
  (swivel)
- Arm Chair (2)

WORK SURFACES
- Standard Desk
- Work Table
- Chalkboard
  (gridded)
- Tackboard
- Projection Screen

STORAGE
- Book Shelf (4)
- General Shelf
- File Cabinet
  (4-drawer)
- Equipment Closet
- Coat Rack, wall-mounted

MAJOR EQUIPMENT
- Radio
- Push-Button Phone
- Typewriter
- Desk Calculator
- Film Projector
- Air Conditioner

MINOR EQUIPMENT
- Clock
- Waste Basket

LIGHTING
- Gooseneck Lamp
- Tensor Lamp
- Drawing Lamp
- Pole Lamp
- Indirect Lighting
- Recessed Lighting
- Rheostat

ENCLOSURE
- Picture Window
- Draperies
  (translucent, cloth)
- Sliding Door
- Walls, flat green,
  painted plaster,
  wood trim
- Wall-Wall Carpeting
- Suspended Ceiling

SERVICES
- Cool Air
- Fresh Air
- Exhaust
- Hot Air
- Thermostate

Problem II, 5-Step, Subject #3

Solution Specifications

SEATING
- Stool
- Freestanding Bench
- Arm Chair
- Easy Chair
- Couch

WORK SURFACES
- Wall Counter
- Freestanding Counter
- Movable Table
- Display Case

STORAGE
- Storage Shelf
- Coat Hook
- Coat Rank

VENDING EQUIPMENT
- Hot Drink Dispenser
- Cold Drink Dispenser
- Milk Dispenser
- Milkshafe Dispenser
- Beer Dispenser
- Sandwich Dispenser
- Canned Food Dispenser
- Ice Cream Dispenser
- Candy Dispenser
- Popcorn
- Coin Changer

OTHER EQUIPMENT
- Microwave Oven
- Warmer Plate
- Warmer Lights
- Refrigerated Cabinet
- Condiment Counter
- Drinking Founctain
- Wastebasket
- Trash Cart
- Air Conditioner
- Ash Tray
- Wall Clock
- Pencil Sharpener
- Campus Phone
- Pay Telephone
- Radio (individual)
- Television (individual)
- Cassette Player (individual)

LIGHTING
- Gooseneck Lamp
- Tensor Lamp
- Area Lighting
- Indirect Lighting
- Incandescent Lighting
- Individually Controlled Lighting
- Rheostat

ENCLOSURE
- Cleresotry Window (tinited glass)
- Skylight
- 6' Partition
- Freestnading Partition
- Walls, cork, plaster, Wood
- Stairs
- Ramp
- Balcony
- Floor, brick
- Multi-Level Ceiling

SERVICES
- Cool Air
- Exhaust
- Fresh Air
- Hot Air
- Chilled Water

Problem II, 10-Step, Subject #3

Solution Specifications

SEATING
- Booth Bench
- Freestanding Bench
- Straight chair
- Arm Chair

WORK SURFACES
- Fixed Table
- Movable Table
- Condiment Table

STORAGE
- Storage Shelf
- Storage Ledge
- Cubbyhole
- Coat Hook

EQUIPMENT
- Automated Vending (central unit, stores, heats, delivers, food selections)
- Automated Table Service (pneumatic tubes, etc., food selected, delivered at table)
- Dollar Bill Changer
- Waste Basket
- Trash Container
- Radio

LIGHTING
- Table Lamp
- Indirect Lighting
- Recessed Lighting
- Individually Controlled Lighting

ENCLOSURE
- Alcove Partition
- Multi-Level Floor
- Depressed Floor
- Wall-Wall Carpeting
- Multi-Level Ceiling

MATERIALS
- Stone
- Wood
- Brick
- Textured, brown grey

Problem II, 15-Step, Subject #1

Solution Specification

SEATING
- Booth Bench
- Arm Chair
- Patio Chair
- Picnic Table Bench

WORK SURFACES
- Booth Table
- Square Table
- Large Table
- Patio Table
- Picnic Table
- Condiment Table

VENDING EQUIPMENT
- Hot Drink Dispenser
- Cold Drink Dispenser
- Milk Dispenser
- Milkshake Dispenser
- Popbottle Dispenser
- Beer Dispenser
- Sandwich Dispenser
- Pastry Dispenser
- Ice Cream Dispenser
- Popcorn Dispenser

OTHER EQUIPMENT
- Microwave Oven
- Hot Plate
- Warner Plate
- Steam Table
- Refrigerated Cabinet
- Freezer
- Fire Place

LIGHTING
- Individually Controlled Lighting

ENCLOSURE
- Sliding Door
- Alcove Partition
- Free Standing Partition
- Screen Wall
- Stairs
- Platform
- Balcony
- Depressed Floor
- Multi-Level Ceiling

Problem III, 5-Step, Subject #1

Solution Specifications

SEATING
- Arm Chair
  - (molded seat, rotatable, tilting)

WORK SURFACES
- Individual Desk or Table
- Conference Table
  - (sloping work surface, natural matte finish wood)
- Equipment Stand
- Display Table
- Chalkboard
- Tackboard
- Projection Screen

STORAGE
- Book Shelf
- Storage Shelf
- Projector Cabinet
- Equipment Storage
- Coat Rack

AUDIO-VISUAL EQUIPMENT
- Radio
- Intercom
- Overhead Projector
- Opaque Projector
- Film Projector
- Video Projector
- Random Access Slide Projector
- Microphone
- Speakers
- Remote Controls
  - (for equipment & environment)

OTHER EQUIPMENT
- Coffee Maker
- Drinking Fountain
- Work Sink

LIGHTING
- Table Lamp
- Gooseneck Lamp
- Spot Light
- Flood Light
- Incandescent Lighting
- Fluorescent Lighting
- Indirect Lighting
- Recessed Lighting
- Variable Lighting
- Rheostat

ENCLOSURE
- Slit Window
- Clerestory Window
- Skylight
- Draperies
  - (opaque)
- Standard Door
  - (with view window)
- Platform
- Wall-Wall Carpeting
- Coved Ceiling

SERVICES
- Cool Air
- Fresh Air
- Hot Air
- Thermostat
- Chilled Water
- Intercom
- T.V. Conduit

All Windows: polariod glass, thermopane

Problem III, 10-Step, Subject #2

Solution Specifications

SEATING
- Arm Chair
- Easy Chair

WORK SURFACES
- Trapezoidal Table
- Round Table
- Chalkboard (metal, gridded)
- Tackboard
- Projection Screen

STORAGE
- File Cabinet
- Equipment Stand
- Equipment Closet
- Coat Rack

AUDIO-VISUAL EQUIPMENT
- Television
- Overhead Projector
- Film Projector
- Video Projector
- Random Access Slide Projector
- Multiple Speakers

OTHER EQUIPMENT
- Push-Button Phone
- Pencil Sharpener
- Waste Basket
- Coffee Maker
- Thermostat

LIGHTING
- Luminous Ceiling
- Movie Lighting
- Variable Lighting
- General Lighting
- Rheostat

ENCLOSURE
- Sliding Windows
- Bay Window
- Skylight
- Draperies
- Standard Door
- Folding Door (or wall)
- Wall-Wall Carpeting

Problem III, 15-Step, Subject #2

Solution Specifications

SEATING
- Desk Chair
  (high back, swivel)
- Side Chair
- Arm chair

WORK SURFACES
- Round Table
- Conference Desk
- Conference Table
- Equipment Stand
- Display Table
- Display Rack
- Chalkboard
- Tackboard
- Felt Board

STORAGE
- Equipment Closet
- Coat Rack
- Coat Closet

AUDIO-VISUAL EQUIPMENT
- Radio
- Television
- Tape REcorder
- Video Tape REcorder
- Stenographic Recorder
- Photo Transmitter
- Computer Graphics Console
- Overhead Projector
- Opaque Projector
- Film Projector
- Video Projector
- Microphone
- Speakers
- Remote Controls
  (for equipment & environment)

OTHER EQUIPMENT
- Wall Calendar
- Wall Clock
- Pencil Sharpener
- Stapler
- Waste Basket

LIGHTING
- Spot Light
- Indirect Lighting
- Recessed Lighting
- Rheostat

ENCLOSURE
- Fixed Window
- Skylight
- Standard Door
- 6' Partition
- Folding Wall
- Stage
- Depressed Floor
- Wall-Wall Carpeting
- Coved Ceiling
- Formed Ceiling

APPENDIX I RESULTS DETAILS

These appendices provide the detailed results generated in the intial processing of the data record from this experiment, which are summarized in the body of the report. They include, the descriptions of the seventy-one meausres synthesized from the data processing and evaluation, individual tables for each measure showing subject scores in each session, and graphic demonstrations of the most important interaction effects.

Appendix I-1 Description of Measures

This lists each measure in the code sequences used to describe measures in the summary tables, with an explanation of the meaning of each measure. Reference should also be made to the explanations given for measure generation in the body of the report and specific details given in Appendices F, G, H.

DESCRIPTION OF MEASURES

MEASURE	DESCRIPTION
1. GENERAL PERFORMANCE	Measures which summarieze the general characteristics of problem-solving, covering the major areas of activity.
1.1 Overall Performance	The most general measures which demonstrate the overall approaches to problem-solving.
1.1.1 # Items Selected	Indicates the number of information item cards selected from the information bank in any one session, a measure of the "quantity" of information utilized.
1.1.2 # Cards Generated	Indicates the number of data or IBM cards generated by the coder to describe the behavior in a given session, a measure of the overall level of activity, since one card was used for each variable.
1.1.3 # Frames Required	Indicates the number of frames on the film record, since frames were recorded at a constant 30 second interval, this is also a measure of time.
1.2 Major Performance	Additional measures of patterns of information selection and useage, supplementing the measures listed above.
1.2.1 # Items Reused	Indicates the number of items which were initially selected and then reused one or more times, in comparison with 1.1.1 suggests the applicability of information selected.

DESCRIPTION OF MEASURES continued

MEASURE	DESCRIPTION
1.2.2 # Reuse Occurrances	Indicates the total number of times that information items were reused in the session, measures the level of reuse activity as compared with selection activity.
1.2.3 # Groups Formed	Indicates the number of groupings of information items throughout the session, whether or initial selection or reuse, measures the level of grouping activity, and suggests the size of groups used.
1.2.4 # Runs Formed	Indicates the number of group sequences, usually selection or reorganization of information, without any other intervening activity, measures the level of activity and suggests the length of sequences.
1.3 Secondary Performance	Measures related to supporting activities rather than the primary information selection and reuse.
1.3.1 # Relationships	Indicates the number of relationships of all types established between groups of information items, measures the degree to which information was interrelated.
1.3.2 # Dispositions	Indicates special treatment given to groups of information items, primarily the removal of items to storage.

DESCRIPTION OF MEASURES continued

MEASURE	DESCRIPTION
1.3.3 # Verbal Notations	Indicates the number of instances in which subjects wrote out "chalk messages" representing additional clarification of their work with the information items.
1.3.4 # Graphic Notations	Indicates the number of instances in which subjects made chalk sketches or drawings representing visualization of configurations suggested by the information items.
<u>1.4 Comparative Performance</u>	Measures related to the comparison between information selection and reuse, representing alternative information emphases.
1.4.1 # Selection Groups	Indicates the fraction of total groups formed, in which the group members were being selected for the first time.
1.4.2 # Reuse Groups	Indicates the complement to the above measure.
1.4.3 Average Size of Selection Groups	Indicates the average number of information items in each selection group.
1.4.4 Average Size of Reuse Groups	Similar to above, both measure the conceptual approach to grouping information in small or large "chunks."

DESCRIPTION OF MEASURES continued

MEASURES	DESCRIPTION
2. DEFINITION INFORMATION	Measures which indicate specific information useage in the information categories related to "problem definition".
2.1 Definition Information Selection	Measures indicating the number of items in each category which were selected from the information bank.
2.1.1 Problem Descriptors Selected	Items related to overall descriptions of the approach taken by the designer and the problem to be solved (see Appendix C-2 Information Bank Structure, category "A").
2.1.2 Process Descriptors Selected	Items related to specific techniques and approaches to organizing and utilizing information (category "B").
2.1.3 Overall Requirements Selected	Items related to the major categories of user needs (category "C").
2.1.4 General Requirements Selected	Items related to more peripheral aspects of problem limitations and requirements, (category "E").
2.1.5 All Definition Information Selected	A total of the numbers of items in the above categories, a gross measure of definition information utilization.

DESCRIPTION OF MEASURES continued

MEASURE	DESCRIPTION
2.2 Definition Information Reuse	Measures indicating the level of utilization of information in these categories, indicating frequency of item reuse in each category; this may represent many items reused a few times or a few items reused many times.
2.2.1 Problem Descriptors Reused	
2.2.2 Process Descriptors Reused	
2.2.3 Overall Requirements Reused	
2.2.4 General Requirements Reused.	
2.2.5 All Definition Information Reused	
3. DEVELOPMENT INFORMATION	Measures which indicate specific information useage in the categories which are primarily related to "problem development" usually expanding on the definition, and leading to the identification of solution alternatives.
3.1 Development Information Selection	
3.1.1 Action Types Selected	Items listing alternative activities which chould be performed by users (category "G").
3.1.2 Design Considerations Selected	Items covering various problem-solving criteria which could be applied to any problem of this type, modifying specific problem considerations (category "H").

DESCRIPTION OF MEASURES continued

MEASURE	DESCRIPTION
3.1.3 Research Information Selected	Items related to human factors standards and psychological man-environment relationships (category "F").
3.1.4 General Information Selected	Items related to previous experience of designers with similar problems, (category "K").
3.1.5 All Development Information Selected	
3.2 Development Information Reuse	
3.2.1 Action Types Reused	
3.2.2 Design Considerations Reused	
3.2.3 Research Information Reused	
3.2.4 General Information Reused	
3.2.5 All Development Information Reused	
4. SOLUTION DESCRIPTION INFORMATION	Measures which indicate specific information useage in categories which supplement the specific solution elements, either providing broader, more conceptual aspects, or adding more specific details to individual elements.

DESCRIPTION OF MEASURES continued

MEASURE	DESCRIPTION
4.1 Solution Description Information Selection	
4.1.1 Element Classes Selected	Items which list different major types of elements (category "L")
4.1.2 Solution Concepts Selected	Items which describe different conceptual approaches to be taken with regard to different aspects of the solution, (category "Z").
4.1.3 Graphic Elements Selected	Items which contain drawings or sketches of different specific elements, illustrating alternative shape configurations, (category "W").
4.1.4 Element Specifications Selected	Items listing different element properties or characteristics (category "X-Y").
4.1.5 All Solution Description Information Selected	
4.2 Solution Description Information Reuse	
4.2.1 Element Classes Reused	
4.2.2 Solution Concepts Reused	
4.2.3 Graphic Elements Reused	
4.2.4 Element Specifications Reused	
4.2.5 All Solution Description Information Reused	

5. SOLUTION-ELEMENT INFORMATION	Measures which indicate the useage of specific physical elements or components in the solution.
<u>5.1 Solution Element Selection</u>	
5.1.1 Material Elements Selected	Items which list alternative material elements, such as food, clothing, books, etc., to be used in the solution environment (category "M-N").
5.1.2 Furniture Elements Selected	Items which list alternative types or forms of furniture (category "O-Q").
5.1.3 Equipment Elements Selected	Items which list alternative types or forms of equipment (category "R-S").
5.1.4 Ancillary Elements Selected	Items which list alternative types or forms of enclosure, walls, doors, windows, etc., and building services (category "T-V").
5.1.5 All Solution Elements Selected	
<u>5.2 Solution Element Reuse</u>	
5.2.1 Material Elements Reused	
5.2.2 Furniture Elements Reused	
5.2.3 Equipment Elements Reused	
5.2.4 Ancillary Elements Reused	
5.2.5 All Solution Elements Reused	
6. SOLUTION CHARACTERISTICS	Measures which describe different properties of the final solutions produced by the subjects.
<u>6.1 Solution Scope</u>	Measures which indicate degree of completeness or "detail" used in describing the solution.

DESCRIPTION OF MEASURES continued

MEASURE	DESCRIPTION
6.1.1 All Solution Items Selected	Indicates the combined totals of All Solution Description Information Selected and All Solution Elements Selected, a gross measure of solution activity.
6.1.2 # Solution Specification Items	Indicates the number of items listed on the solution specification sheet accompanying each drawing in the final evaluation, elements provided.
6.1.3 # Drawing Details	Indicates the number of separate aspects included on the subject's solution drawing, such as door and window openings, furniture, partitions, explanatory notes, level changes, etc.
<u>6.2 Solution Parameters</u>	Measures which indicate degree of complexity in the solution configuration, relative "richness" of solution thought.
6.2.1 # Square Feet	The area of the solution space specified by the subject, measured in square feet, either as given by subject or estimated by experimenter. (X100)
6.2.2 # Room Divisions	Indicates the "breakup" of the solution space, usually by walls, partitions, or furniture groupings.
6.2.3 # Functional Areas	Indicates areas within the solution space designed for specific functions or activities as suggested by verbal notations, groupings of furniture or equipment.
6.2.4 # Level Changes	Indicates number of different floor levels in the solution space, multi-floors, platforms, balconies, etc.

DESCRIPTION OF MEASURES continued

MEASURE	DESCRIPTION
7. SOLUTION EVALUATION	Measures which indicate the scores given by evaluators on different criteria as applied to the solution drawings and specification sheets.
7.1 Solution Evaluation Criteria	Scores on individual criteria as described in Appendix H-1.
7.1.1 Comprehensive	
7.1.2 Effective	
7.1.3 Efficient	
7.1.4 Aesthetic	
7.1.5 Innovative	
7.1.6 Complete	
7.2 Solution Evaluation Totals	Measures represent the comparative socres generated as the sum of the evaluator's ranking and rating scores for the individual evaluation criteria.
7.2.1 All Criteria Ranking and Rating Combined	
7.2.2 All Ranking Criteria	
7.2.3 All Rating Criteria	

Appendix I-2 Experimental Results Tables

This lists the numerical results, following the sequence of measures as described in Appendix I-1, the details of the arrangement of the tables are given in Figure 5-1 in the text. Significance levels as determined by the analysis of variance are given beneath each table.

EXPERIMENTAL RESULTS TABLES

Prob.	10-STEP (1)	(2)	(3)		15-STEP Subjects (4)	(5)	(6)		5-STEP (7)	(8)	(9)		Prob. Total

1.1.1 # Items Selected

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
I.	417	361	375	384	237	263	144	215	236	292	486	338	312
II.	243	156	223	207	233	232	136	200	218	198	450	289	232
III.	177	159	190	175	204	226	113	181	244	195	400	280	212
ALL	279	225	263	256	225	240	131	199	233	228	445	302	252

Significance: Problems .01; Subjects .01; StratxProb .01

1.1.2 # Cards Generated

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
I.	805	1138	1357	1100	651	593	715	653	641	416	965	674	809
II.	674	413	1152	746	622	522	440	528	587	447	941	658	644
III.	397	376	603	459	528	544	605	559	522	442	746	570	529
ALL	625	642	1037	768	600	553	587	580	583	435	884	634	661

Sig: Problem .01; Subjects .01; StratxProb .05

1.1.3 # Frames Required

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
I.	850	768	846	821	787	825	760	791	947	910	890	916	843
II.	793	770	803	789	812	759	792	788	870	901	865	879	818
III.	376	440	544	453	717	667	740	708	706	700	695	700	621
ALL.	673	659	731	688	772	750	764	762	841	837	817	832	761

Sig: Strategy .01; Problem .01; StratxProb .01

1.2.1 # Items Reused

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
I.	92	496	206	165	81	106	129	105	87	46	166	100	123
II.	107	54	200	120	92	14	100	69	108	41	127	92	94
III.	24	53	102	60	99	107	95	100	82	81	72	78	79
ALL.	74	101	169	115	91	76	108	91	92	56	122	90	99

Sig: Problem .10; Subject .10

1.2.2 # Reuse Occurrances

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
I.	108	252	452	271	133	138	341	204	169	54	206	143	206
II.	163	79	556	266	152	18	207	126	216	43	251	170	187
III.	27	84	213	108	138	129	275	181	125	91	93	103	131
ALL.	99	138	407	215	141	95	274	170	170	63	183	139	175

Sig: Subject .05

	[illegible]-STEP				15-STEP				5-STEP				
Prob.	(1)	(2)	(3)		Subjects (4)	(5)	(6)		(7)	(8)	(9)		Prob. Total

1.2.3 # Groups Formed

I.	128	241	252	207	133	94	102	110	121	96	138	118	145
II.	114	73	236	141	107	68	76	84	99	97	160	119	114
III.	49	73	153	92	104	85	100	96	102	99	146	116	101
ALL	97	129	214	147	115	83	93	97	107	97	148	118	120

Sig: Problem .05; Subject .05; StratxProb .10

1.2.4 # Runs Formed

I.	35	39	92	55	33	19	36	29	34	12	36	27	37
II.	43	19	39	34	26	24	26	26	34	36	38	36	32
III.	16	16	23	18	24	36	24	28	24	24	27	25	24
ALL	31	25	51	36	28	26	29	28	31	24	34	29	31

Sig: Problem .10; StratxProb .10

1.3.1 # Relationships

I.	149	277	272	233	143	65	93	100	117	27	246	130	154
II.	98	55	246	133	95	32	45	57	92	115	170	126	105
III.	145	44	166	118	77	40	82	66	89	76	143	103	96
ALL	131	125	228	161	105	46	73	75	99	73	186	119	118

Sig: Problem .10; Subject .05.

1.3.2 # Dispositions

I.	114	234	246	198	119	95	103	106	109	37	8	51	118
II.	122	76	113	104	105	69	27	67	50	75	57	61	77
III	25	57	15	32	71	87	98	85	42	63	88	64	61
ALL	87	122	125	111	98	84	76	86	67	58	51	59	85

Sig: Strategy .05; Problem .05; StratxProb .05

1.3.3 # Verbal Notations

I.	5	5	2	4	3	5	7	5	0	1	8	3	4
II.	21	17	1	13	15	10	4	10	4	7	5	5	9
III	8	10	6	8	10	27	16	18	7	1	6	5	10
ALL	11	11	3	8	9	14	9	11	3	3	6	4	8

Sig: Problem .10

[illegible]

Prob.	[illegible] (1)	(2)	(3)		15-STEP (4)	(5)	(6)		5-STEP (7)	(8)	(9)		Prob. Total
1.3.4 # Graphic Notations													
I.	1	0	0	0	3	8	6	6	0	0	3	1	2
II.	4	13	3	7	6	13	3	7	1	5	2	3	6
III.	6	11	2	6	10	19	5	11	9	10	9	9	9
ALL	4	8	2	4	6	13	5	8	3	5	5	4	6
Sig: Problem .01; Subject .05													
1.4.1 # Selection Groups													
I.	90	121	100	104	89	50	18	52	59	74	90	74	77
II.	46	53	38	46	49	59	17	42	43	65	83	64	50
III.	26	39	75	47	47	46	14	36	53	50	91	65	49
ALL	54	71	71	65	62	52	16	43	52	63	88	68	59
Sig: Problem .01; Subject .01; StratxProb .05													
1.4.2 # Reuse Groups													
I.	38	120	152	103	44	44	84	57	62	22	48	44	68
II.	68	19	190	92	56	9	57	41	49	26	63	46	60
III.	18	32	72	41	51	36	83	57	42	44	52	46	48
ALL	41	57	138	79	50	30	75	52	51	31	54	45	59
Sig: Subject .05													
1.4.3 Average Size of Selection Groups													
I.	5	3	4	4	3	5	9	6	4	4	6	5	5
II.	5	2	5	4	5	4	8	6	5	3	5	4	5
III	5	4	3	4	4	5	8	6	5	4	4	4	5
ALL	5	3	4	4	4	5	8	6	5	4	5	4	5
Sig: Subject .05													
1.4.4 Average Size of Reuse Groups													
I.	3	2	3	3	3	3	4	3	3	3	4	3	3
II.	3	6	3	4	3	2	4	3	5	2	4	4	4
III.	4	3	3	3	3	3	3	3	3	2	2	2	3
ALL	3	4	3	3	3	3	4	3	4	2	4	3	3

Prob.	15-[illegible] (1)	(2)	(3)		15-[illegible] Subjects (4)	(5)	(6)		5-STEP (7)	(8)	(9)		Prob. Total
2.1.1 Problem Descriptors Selected													
I.	12	3	7	7	8	6	10	8	5	8	11	8	8
II.	6	7	7	7	9	3	12	8	12	8	13	11	9
III.	6	3	6	5	12	6	9	9	11	8	14	11	8
ALL	8	4	7	6	10	5	10	8	9	8	13	10	8
Sig: Subject .05													
2.1.2 Process Descriptors Selected													
I.	17	5	3	8	4	0	18	7	12	14	18	15	10
II.	0	2	0	1	0	0	0	0	9	12	28	16	6
III.	0	1	0	0	1	0	0	0	4	12	24	13	5
ALL	6	3	1	3	1	0	6	2	8	13	23	15	7
Sig: Strategy .05; Problem .10; Subject .05													
2.1.3 Overall Requirements Selected													
I.	25	15	21	20	14	6	18	13	16	26	26	23	19
II.	12	14	16	14	20	5	20	15	22	16	29	22	17
III.	8	7	13	9	25	10	22	19	21	21	29	24	17
ALL	15	12	17	15	20	7	20	16	20	21	28	23	18
Sig: Subject .01; StratxProb .05													
2.1.4 General Requirements Selected													
I.	14	15	6	12	17	5	10	11	16	16	15	16	13
II.	10	12	20	14	19	5	6	10	17	15	0	11	12
III.	9	3	12	8	14	5	7	9	21	21	17	20	12
ALL	11	11	13	11	17	5	8	10	18	17	11	15	12
Sig: Subject .10													
2.1.5 All Definition Information Selected													
I.	68	38	37	48	43	17	56	39	49	64	70	61	49
II.	28	35	43	35	48	13	38	33	60	51	70	60	43
III.	23	14	31	23	52	21	38	35	57	62	84	68	42
ALL	40	29	37	35	48	17	44	36	55	59	75	63	45
Sig: Strategy .01; Subject .05													

15-... 5-STEP

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
2.2.1 Problem Descriptors Reused													
I.	0	0	0	0	3	0	29	11	0	0	11	4	5
II.	2	0	0	1	7	0	11	6	3	0	5	3	3
III.	0	0	0	0	6	0	9	5	0	0	7	2	2
ALL	1	0	0	1	5	0	16	7	1	0	8	3	3
Sig: Subject .01													
2.2.2 Process Descriptors Reused													
I.	1	1	1	1	0	0	31	10	5	0	9	5	5
II.	0	0	0	0	1	0	0	0	3	1	16	7	2
III.	0	0	0	0	0	0	0	0	0	12	0	4	1
ALL	0	0	0	0	0	0	10	4	2	4	8	5	3
2.2.3 Overall Requirements Reused													
I.	0	14	0	5	0	0	59	20	0	0	21	7	10
II.	8	6	33	16	14	5	34	18	22	11	0	11	15
III.	2	0	7	3	12	2	49	21	4	4	4	4	9
ALL	3	7	13	8	9	2	47	19	9	5	8	7	12
Sig: Subject .01													
2.2.4 General Requirements Reused													
I.	0	11	3	5	0	0	7	2	4	0	0	1	3
II.	4	0	0	1	3	0	9	4	0	0	0	0	2
III.	0	0	0	0	0	0	10	3	0	1	0	0	1
ALL	1	4	1	2	1	0	9	3	1	0	0	0	2
Sig: Subject .01													
2.2.5 All Definition Information Reused													
I.	1	26	4	10	3	0	126	43	9	0	41	17	23
II.	14	6	33	18	25	5	54	28	28	12	21	20	22
III.	2	0	7	3	18	2	68	29	4	17	11	11	14
ALL	6	11	15	10	15	2	83	33	14	10	24	16	20
Sig: Subject .01													

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
[illegible] Action Types Selected													
I.	1	22	[illegible]	24	0	15	0	5	16	25	27	23	1[illegible]
II.	11	24	[illegible]	20	12	10	10	11	30	30	32	31	20
III.	[illegible]	11	19	14	12	15	11	13	19	13	28	22	16
ALL	1[illegible]	21	[illegible]	1[illegible]	[illegible]	13	7	9	22	24	29	25	18
[illegible]: [illegible] .0[illegible]; Problem .10; Subject .01; StratxProb .05													
[illegible] Design Considerations Selected													
I.	[illegible]	[illegible]	[illegible]	41	2[illegible]	1[illegible]	25	23	36	2[illegible]	50	3[illegible]	34
II.	[illegible]	[illegible]	[illegible]	20	[illegible]	26	17	17	36	34	48	39	20
III.	[illegible]	[illegible]	[illegible]	1[illegible]	23	23	24	23	28	29	39	32	24
ALL	[illegible]	[illegible]	[illegible]	[illegible]	19	22	22	21	33	30	46	36	2[illegible]
[illegible]: [illegible] .10; Problems .01; Subject .01; StratxProb.01													
[illegible] Information Selected													
I.	[illegible]	[illegible]	[illegible]	[illegible]	15	46	0	20	20	1[illegible]	40	26	32
II.		[illegible]	[illegible]	[illegible]	17	[illegible]	[illegible]	31	7	0	64	24	25
III.		[illegible]	[illegible]	[illegible]	9	5[illegible]	0	22	23	0	51	25	26
ALL	[illegible]	[illegible]	3[illegible]	34	14	57	1	24	17	6	52	25	2[illegible]
[illegible]: Subject .01													
[illegible] General Information Selected													
I.	[illegible]	[illegible]	1	[illegible]	3[illegible]	27	1	20	[illegible]	15	31	1	2[illegible]
II.	[illegible]	[illegible]	10	1[illegible]	0	1	[illegible]	9	12	1	1[illegible]	10	12
III.	1	[illegible]	[illegible]	14	23	21	0	15	11	11	10	11	13
ALL	[illegible]	2[illegible]		1[illegible]	1[illegible]	[illegible]	3	14	10	9	20	13	16
[illegible] All Development Information Selected													
I.	[illegible]	[illegible]	1[illegible]	140	[illegible]3	106	2[illegible]	68	80	[illegible]6	148	105	104
II.	[illegible]	[illegible]	[illegible]	[illegible]	60	124	40	75	85	65	163	104	[illegible]6
III.	[illegible]	[illegible]	[illegible]	[illegible]	6[illegible]	115	35	72	81	58	128	89	79
ALL	1[illegible]	[illegible]	1[illegible]	[illegible]	[illegible]	115	34	72	82	70	146	99	90
[illegible]: Problems .01; Subject .01; StratxProb .01													

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
[illegible] Reused													
I.	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	0	2	[illegible]	24	0	25	20
II.	[illegible]	[illegible]	[illegible]	[illegible]	10	1	12	8	32	12	3	17	22
III.	11	0	24	11	0	16	3	6	19	0	0	6	[illegible]
ALL	[illegible]	21	51	[illegible]	3	[illegible]	5	5	35	12	1	16	17
Sig: Problem .0[illegible]; Subject .01; StratxProb .10													
[illegible] Design Considerations Reused													
I.	[illegible]	49	[illegible]	25	1[illegible]	15	73	34	1	0	11	4	24
II.	[illegible]	3	[illegible]	[illegible]	6	0	55	20	60	1	0	20	22
III.	[illegible]	0	[illegible]	11	0	2[illegible]	54	27	49	5	3	13	19
ALL	[illegible]	1[illegible]	[illegible]	24	[illegible]	14	61	27	37	2	5	14	22
Sig: Subject .01													
[illegible] Research Information Reused													
I.	[illegible]	[illegible]	[illegible]	55	0	0	0	0	0	0	0	0	1[illegible]
II.	[illegible]	[illegible]	[illegible]	24	0	0	6	2	0	0	0	0	9
III.	[illegible]	4	[illegible]	1	0	0	0	0	0	0	0	0	0
ALL	[illegible]	1[illegible]	[illegible]	27	0	0	2	1	0	0	0	0	9
Sig: Strategy .0[illegible]; Problem .01; Subject .05; StratxProb .01													
[illegible] General Information Reused													
I.	[illegible]	11	1	4	41	17	0	19	3	9	33	15	13
II.	14	1[illegible]	[illegible]	[illegible]	0	1	9	3	[illegible]	0	8	5	10
III.	1	15	0	5	2[illegible]	17	0	15	5	5	0	3	8
ALL	[illegible]	14	1[illegible]	11	23	12	3	12	5	5	14	8	10
[illegible] All Development Reused													
I.	[illegible]	11[illegible]	1[illegible]	124	54	37	73	55	58	33	44	45	75
II.	[illegible]	63	22[illegible]	117	16	2	[illegible]2	33	100	13	11	41	64
III.	1[illegible]	1[illegible]	[illegible]	[illegible]	27	61	57	48	72	10	3	28	35
ALL	46	66	1[illegible]	[illegible]	32	33	71	45	77	19	19	38	5[illegible]
Sig: Problem .05; Subject .01; StratxProb .10													

Prob.	(1)	(2)	(3)	10-STEP	(4)	(5)	(6)	15-STEP	(7)	(8)	(9)	5-STEP	Prob. Total

Subjects

4.1.1 Element Classes Selected

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
I.	27	34	35	32	9	23	3	12	16	26	44	29	24
II.	8	0	18	9	4	3	0	2	6	0	26	11	7
III.	9	7	14	10	8	5	0	4	8	5	32	16	10
ALL	15	14	22	17	7	10	1	6	10	10	34	18	14

Sig: Problem .01; Subject .01

4.1.2 Solution Concepts Selected

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
I.	29	9	32	23	41	30	39	37	15	37	31	28	29
II.	33	7	26	22	49	39	33	40	35	51	40	42	35
III.	17	13	17	16	36	26	31	31	30	26	20	25	24
ALL	26	10	25	20	42	32	34	36	27	38	30	32	29

Sig: Strategy .10; Problem .05; Subject .10

4.1.3 Graphic Elements Selected

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
I.	10	7	7	8	11	9	0	7	1	5	1	2	6
II.	13	8	1	7	10	0	8	6	1	12	3	5	6
III.	1	3	2	2	0	4	1	2	2	6	1	3	2
ALL	8	6	3	6	7	4	3	5	1	8	2	4	5

Sig: Problem .10

4.1.4 Element Specifications Selected

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
I.	2	9	27	13	0	12	0	4	1	5	18	8	8
II.	13	6	4	8	0	8	0	3	0	3	5	3	4
III.	0	1	15	5	0	0	0	0	3	0	20	8	4
ALL	5	5	15	9	0	7	0	2	1	3	14	6	6

Sig: Subject .05

4.1.5 All Solution Description Information Selected

Prob.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		Prob. Total
I.	68	59	101	76	61	74	42	59	33	73	94	67	67
II.	67	21	49	46	63	50	41	51	42	66	74	61	53
III.	27	24	48	33	44	35	32	37	43	37	73	51	40
ALL	54	35	66	52	56	53	38	49	39	59	80	59	53

Sig: Problem .01; Subject .05

Prob.	[illegible]				[illegible] Subjects				5-STEP				Prob. Total
	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		
4.2.1 Element Classes Reused													
I.	14	10	64	29	5	6	3	5	39	6	51	32	22
II.	9	0	43	17	2	0	0	1	0	0	22	7	8
III.	5	4	52	20	12	7	0	6	3	2	22	9	12
ALL	9	5	53	22	6	4	1	4	14	3	32	16	14
Sig: Problem .01; Subject .01; SratxProb .10													
4.2.2 Solution Concepts Reused													
I.	0	3	13	5	49	39	115	67	25	0	22	16	29
II.	52	2	141	65	75	11	61	49	83	6	42	44	53
III.	0	5	47	17	40	18	149	69	19	21	3	14	34
ALL	17	3	67	29	55	23	108	62	42	9	22	25	39
Sig: Subject .05													
4.2.3 Graphic Elements Reused													
I.	0	11	0	4	1	2	0	1	0	0	0	0	2
II.	0	0	0	0	2	0	4	2	0	4	0	1	1
III.	0	0	0	0	4	1	0	2	0	5	0	2	1
ALL	0	4	0	1	2	1	1	2	0	3	0	1	1
4.2.4 Element Specifications Reused													
I.	14	1	21	12	0	10	0	3	0	0	1	0	5
II.	0	0	15	5	0	0	0	0	0	0	10	3	3
III.	0	0	1	0	0	0	0	0	0	0	8	3	1
ALL	5	0	12	6	0	3	0	1	0	0	6	2	3
Sig: Subject .05													
4.2.5 All Solution Description Information Reused													
I.	28	25	98	50	55	57	118	77	64	6	74	48	58
II.	61	2	199	87	79	11	65	52	83	10	74	56	65
III.	5	9	33	16	56	26	149	77	22	28	33	28	40
ALL	31	12	110	51	63	31	111	68	56	15	60	44	54
Sig: Subject .05													

Prob.	Subjects (1)	(2)	(3)	10-STEP	(4)	(5)	(6)	15-STEP	(7)	(8)	(9)	5-STEP	Prob. Total

5.1.1 Material Elements Selected

Prob.	(1)	(2)	(3)	10-STEP	(4)	(5)	(6)	15-STEP	(7)	(8)	(9)	5-STEP	Prob. Total
I.	4	41	9	18	1	9	4	5	21	0	65	29	17
II.	37	0	5	14	41	3	0	15	3	0	54	19	16
III.	1	20	0	7	10	1	0	4	0	1	61	21	10
ALL	14	20	5	13	17	4	1	8	8	0	60	23	15

Sig: Subject .01

5.1.2 Furniture Elements Selected

Prob.	(1)	(2)	(3)	10-STEP	(4)	(5)	(6)	15-STEP	(7)	(8)	(9)	5-STEP	Prob. Total
I.	28	17	14	20	11	21	0	11	20	20	25	22	17
II.	15	6	9	10	4	11	0	5	5	0	11	5	7
III.	14	11	11	12	15	10	0	8	4	0	12	5	9
ALL	19	11	11	14	10	14	0	8	10	7	16	11	11

Sig: Problem .01; Subject .01; StratxProb .05

5.1.3 Equipment Elements Selected

Prob.	(1)	(2)	(3)	10-STEP	(4)	(5)	(6)	15-STEP	(7)	(8)	(9)	5-STEP	Prob. Total
I.	45	30	25	33	4	15	0	6	10	13	43	22	21
II.	0	8	8	5	18	6	0	8	13	0	38	17	10
III.	7	16	11	11	9	24	0	11	19	0	12	10	11
ALL	17	18	15	17	10	15	0	8	14	4	31	16	14

Sig: Problem .10; Subject .10

5.1.4 Ancillary Elements Selected

Prob.	(1)	(2)	(3)	10-STEP	(4)	(5)	(6)	15-STEP	(7)	(8)	(9)	5-STEP	Prob. Total
I.	19	26	17	21	18	21	0	13	0	8	6	5	13
II.	16	5	10	10	13	16	9	13	1	7	32	13	12
III.	10	10	6	9	1	12	0	4	18	32	23	24	12
ALL	15	14	11	13	11	16	3	10	6	16	20	14	12

Sig. StratxProb .05

5.1.5 All Solution Elements Selected

Prob.	(1)	(2)	(3)	10-STEP	(4)	(5)	(6)	15-STEP	(7)	(8)	(9)	5-STEP	Prob. Total
I.	96	114	65	92	34	66	4	35	51	41	139	77	68
II.	68	19	32	40	76	36	9	40	22	7	135	55	45
III.	32	57	28	39	35	47	0	27	41	33	108	61	42
ALL	65	63	42	57	48	50	4	34	38	27	127	64	52

Sig: Problem .05; Subject .01

Prob.	10-STEP Subjects (1)	(2)	(3)		15-STEP (4)	(5)	(6)		5-STEP (7)	(8)	(9)		Prob. Total
5.2.1 Material Elements Reused													
I.	0	14	0	5	0	0	7	2	0	0	44	15	7
II.	0	0	10	3	0	0	0	0	0	0	0	0	1
III.	1	24	0	8	13	0	0	4	0	4	8	4	6
ALL	0	13	3	5	4	0	2	2	0	1	17	6	5
5.2.2 Furniture Elements Reused													
I.	0	17	53	23	10	12	0	7	17	6	2	8	13
II.	0	3	52	18	1	0	0	0	1	0	33	11	10
III.	2	13	32	16	19	18	0	12	6	0	13	6	11
ALL	1	11	46	19	10	10	0	7	8	2	16	9	11
Sig: Subject .01													
5.2.3 Equipment Elements Reused													
I.	0	6	68	25	3	15	0	6	8	8	1	6	12
II.	0	1	21	7	15	0	0	5	1	0	74	25	12
III.	1	14	7	7	0	12	0	4	9	0	6	5	5
ALL	0	7	32	13	6	9	0	5	6	2	27	12	10
5.2.4 Ancillary Elements Reused													
I.	5	16	12	11	9	17	0	9	0	1	0	0	7
II.	17	4	10	10	11	0	0	4	0	0	38	13	9
III.	0	5	1	2	5	10	0	5	12	32	14	19	9
ALL	7	8	8	8	8	9	0	6	4	11	17	11	8
5.2.5 All Solution Elements Reused													
I.	5	53	133	64	22	44	7	24	25	15	47	29	39
II.	17	8	93	39	27	0	0	9	2	0	145	49	32
III.	4	56	40	33	37	40	0	26	27	36	41	35	31
ALL	9	39	89	45	29	28	2	20	18	17	78	38	34
Sig: Subject .05													

Prob.	10-STEP (1)	(2)	(3)	15-STEP Subjects (4)	(5)	(6)	5-STEP (7)	(8)	(9)				Prob. Total
6.1.1 All Solution Items Selected													
I.	164	173	166	168	95	140	46	94	84	114	233	144	135
II.	135	40	81	85	139	86	50	92	64	73	209	115	97
III.	59	81	76	72	79	82	32	64	84	70	181	112	83
ALL	119	98	108	108	104	103	43	83	77	86	208	124	105
Sig: Problem .01; Subject .01; StratxProb .10													
6.1.2 # Solution Specification Items													
I.	74	45	44	54	20	37	11	23	23	29	57	36	38
II.	24	30	26	27	37	39	17	31	20	16	60	32	30
III.	13	34	30	26	33	48	10	30	51	31	30	37	31
ALL	37	36	33	36	30	41	13	28	31	25	49	35	33
6.1.3 # Drawing Details													
I.	7	16	14	12	23	15	13	17	13	12	18	14	15
II.	15	35	16	22	23	22	18	21	12	14	16	14	19
III.	9	18	11	13	16	20	13	16	14	16	10	13	14
ALL	10	23	14	16	21	19	15	18	13	14	15	14	16
Sig: Problem .05; Subject .05													
6.2.1 # Square Feet (x10)													
I.	2	5	3	3	4	2	8	5	4	0	4	3	4
II.	6	170	40	72	54	20	23	32	35	12	12	20	41
III	4	4	7	5	6	11	40	19	13	16	5	11	12
ALL	4	60	17	27	21	11	24	19	17	9	7	11	19
Sig: Problem .10													
6.2.2 # Room Divisions													
I.	4	2	2	3	4	2	8	5	1	2	9	4	6
II.	6	15	5	9	15	6	6	9	3	5	4	4	7
III	2	2	2	2	3	6	8	6	3	3	3	3	4
ALL	4	6	3	4	7	5	7	6	2	3	5	4	5
Sig: Problem .10													

Prob.	10-STEP (1)	(2)	(3)		15-STEP (4)	(5)	(6)		5-STEP (7)	(8)	(9)		Prob. Total
6.2.3 # Functional Areas													
I.	5	5	3	4	7	3	11	7	6	2	16	8	6
II.	9	15	8	11	17	12	9	13	8	9	14	10	11
III.	3	6	5	5	5	7	11	8	5	7	9	7	6
ALL	6	9	5	7	10	7	10	9	6	6	13	8	8
Sig: Problem .05													
6.2.4 # Level Changes													
I.	2	1	1	1	2	1	1	1	1	1	2	1	1
II.	3	2	2	2	4	1	2	2	3	1	2	2	2
III.	1	2	2	2	1	2	1	1	2	2	2	2	2
ALL	2	2	2	2	2	1	1	2	2	1	2	2	2
Sig: Problem .10													
7.1.1 COMPREHENSIVE													
I.	6	3	3	4	3	3	8	5	6	8	6	7	5
II.	6	4	6	5	2	4	7	4	7	7	3	6	5
III.	7	5	5	6	3	4	7	5	6	4	3	4	5
ALL	6	4	5	5	3	4	7	5	6	6	4	6	5
Sig: Subject .01; StratxProb .05													
7.1.2 EFFECTIVE													
I.	6	4	3	4	3	2	8	4	6	9	7	7	5
II.	5	5	5	5	3	2	8	4	5	7	5	6	5
III	7	4	5	5	3	4	8	5	6	4	3	4	5
ALL	6	4	4	5	3	3	8	5	6	7	5	6	5
Sig: Subject .01; StratxProb .05													
7.1.3 EFFICIENT													
I.	4	5	2	4	5	1	8	5	6	9	7	7	5
II.	6	8	6	7	5	2	8	5	5	4	2	4	5
III	8	5	5	6	3	5	8	5	5	5	2	4	5
ALL	6	6	4	5	4	3	8	5	5	6	4	5	5
Sig: Subject .05; StratxProb .05													

Prob.	10-STEP (1)	(2)	(3)		15-STEP Subjects (4)	(5)	(6)		5-STEP (7)	(8)	(9)		Prob. Total

7.1.4 AESTHETIC

I.	5	5	3	4	3	4	8	5	8	9	5	7	6
II.	7	6	5	6	1	5	7	4	5	5	3	4	5
III.	7	4	5	5	5	5	8	6	6	4	2	4	5
ALL	6	5	4	5	3	5	8	5	6	6	3	5	5

Sig: Subject .01; StratxProb .01

7.1.5 INNOVATIVE

I.	5	5	7	6	1	4	6	4	8	9	4	7	6
II.	7	5	5	6	3	5	4	4	6	5	5	5	5
III.	8	3	6	6	4	2	8	5	8	4	3	5	5
ALL	7	5	6	6	3	4	6	4	7	6	4	6	5

7.1.6 COMPLETE

I.	6	3	4	4	1	2	8	4	5	9	6	7	5
II.	8	4	8	7	2	3	6	4	6	6	3	5	5
III.	7	5	6	6	3	3	8	5	7	3	3	4	5
ALL	7	4	6	6	2	3	7	4	6	6	4	5	5

Sig: Subject .01

7.2.1 ALL CRITERIA

I.	31	26	23	27	16	16	45	25	39	51	34	41	31
II.	40	33	36	36	15	22	39	25	34	35	21	30	31
III.	45	27	31	34	20	23	46	30	37	24	16	26	30
ALL	38	29	30	33	17	20	43	27	37	37	23	32	31

Sig: Subject .01; StratxProb .01

7.2.2 ALL RANKING CRITERIA

I.	30	25	21	25	14	14	45	24	38	52	32	41	30
II.	42	34	38	38	16	23	41	27	35	36	21	31	32
III.	45	27	31	34	20	23	47	30	38	23	16	26	30
ALL	39	29	30	33	17	20	44	27	37	37	23	32	31

Sig: Subject .01; StratxProb .01

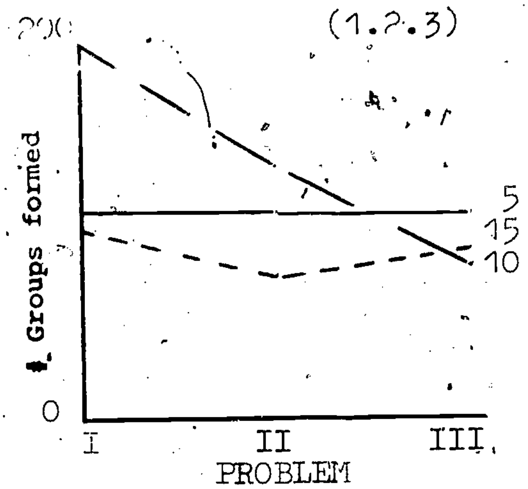
[illegible] RESULTS, TABLES

Prob.	[illegible]				15-[illegible]				5-STEP				Prob. Total
	Subjects												
	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)		
7.2.3 ALL RATING CRITERIA													
I.	31	27	25	[illegible]	17	17	45	26	39	50	35	41	32
II.	37	31	33	34	14	20	36	23	33	33	20	29	29
III.	44	26	31	34	20	22	45	29	35	24	15	25	29
ALL	37	28	30	32	17	20	42	26	36	36	23	32	30

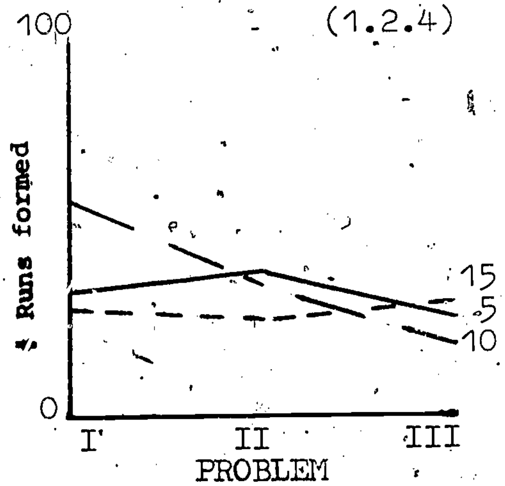
Sig: Subject .01; StratxProb .01

Appendix I-3 Major Interaction Graphs

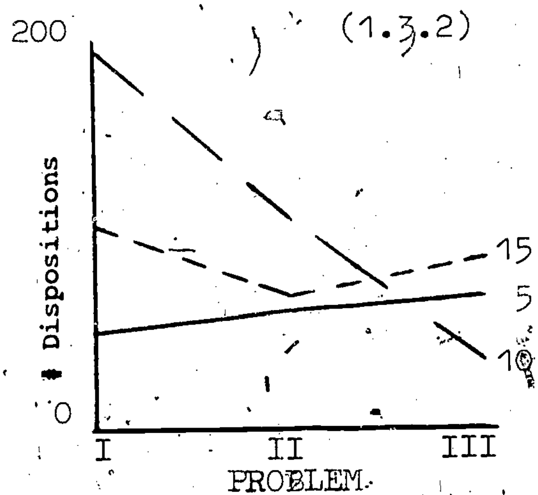
This provides a selected series of graphs similar to those shown in Figure 5-2, demonstrating the changes in scores over three test sessions for the three test strategies (5, 10, 15 step) on the given measures. The three problems are indicated by roman numerals, corresponding to the order of presentation, and the three problems as described in the report. The measures are described by their code number, above the graph, and the range and type of measure are indicated on each graph. Strategies are indicated by a "solid" line = 5-step, a "broken" line = 10-step, and a "dashed" line = 15-step. The significance level for strategy-problem interaction is provided beneath each graph, where applicable.



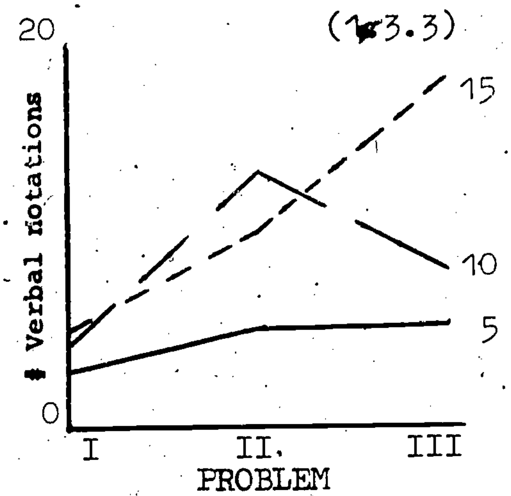
Interaction p = .10

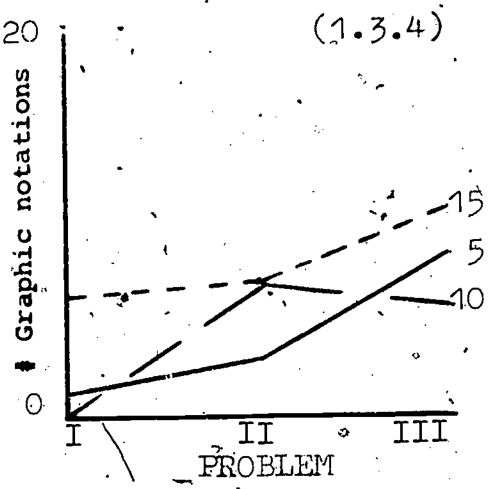


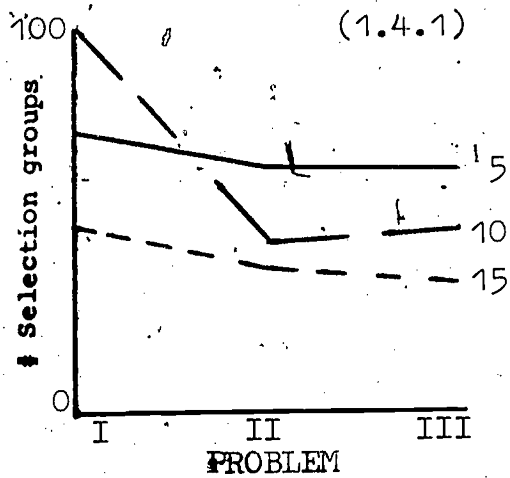
Interaction p = .10



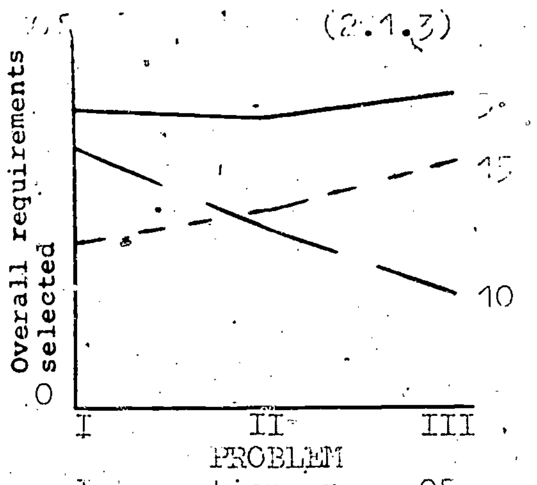
Interaction p = .05



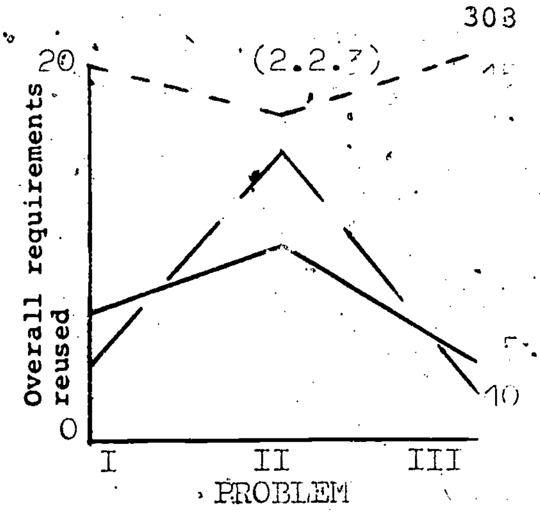


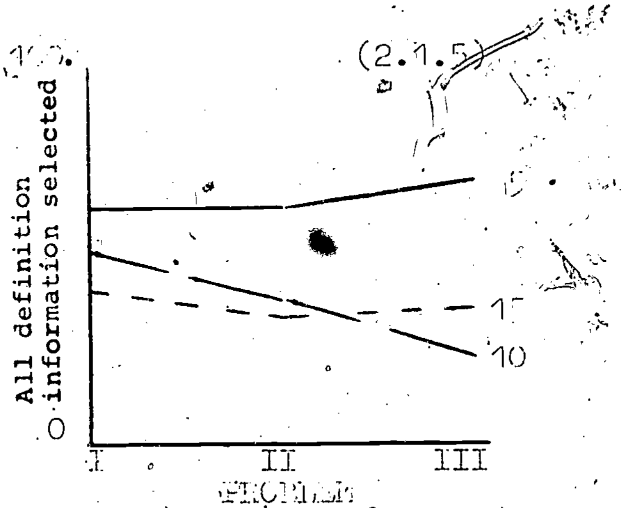


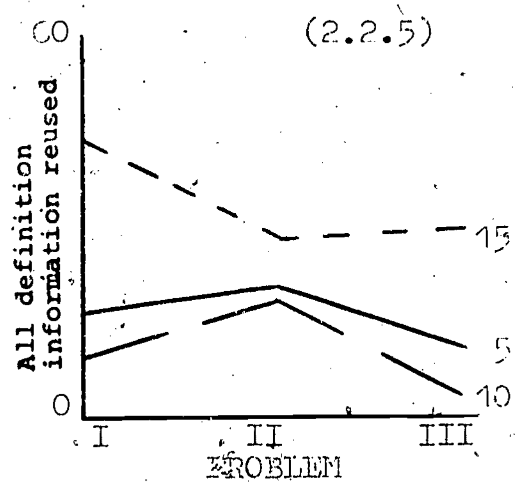
Interaction p = .05

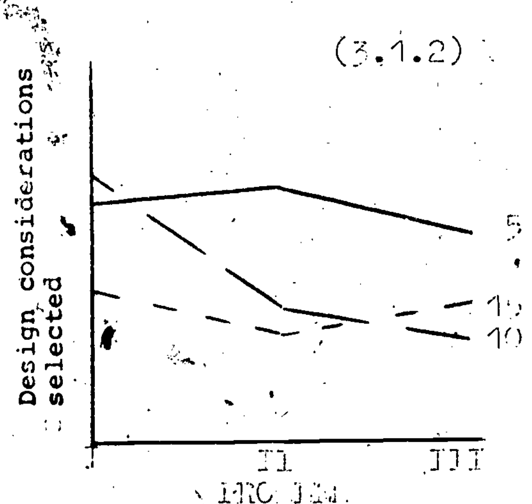


Interaction p = .05

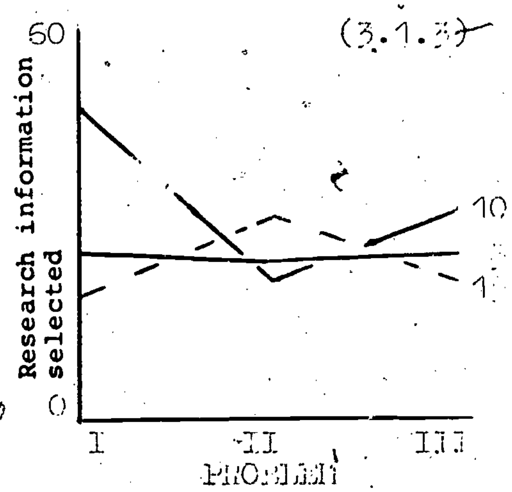


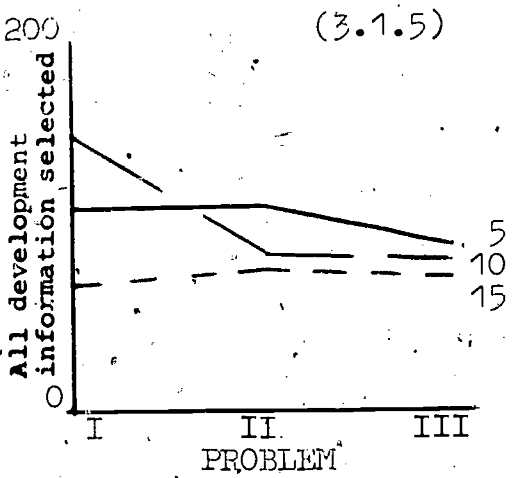




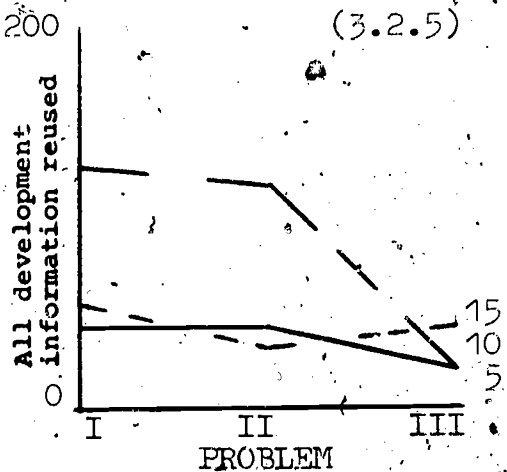


Interaction p = .01

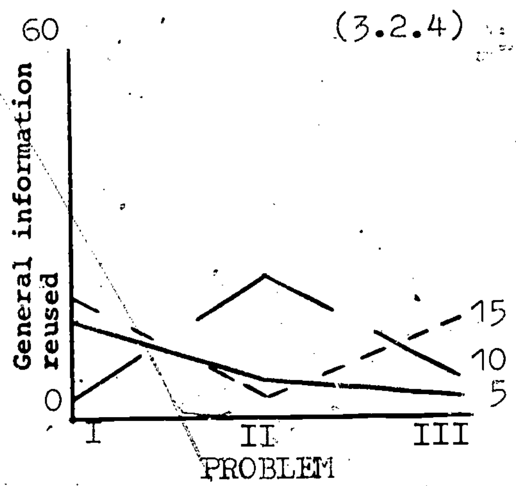


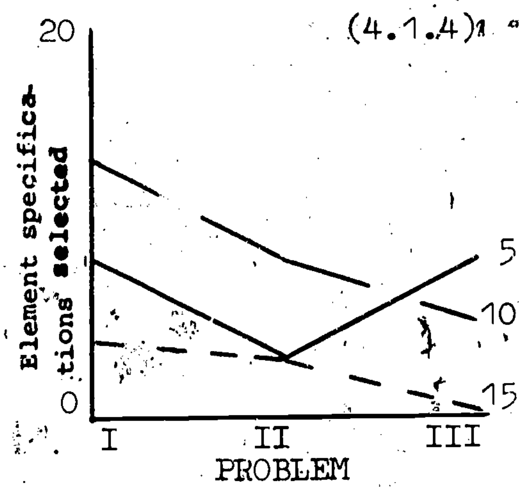


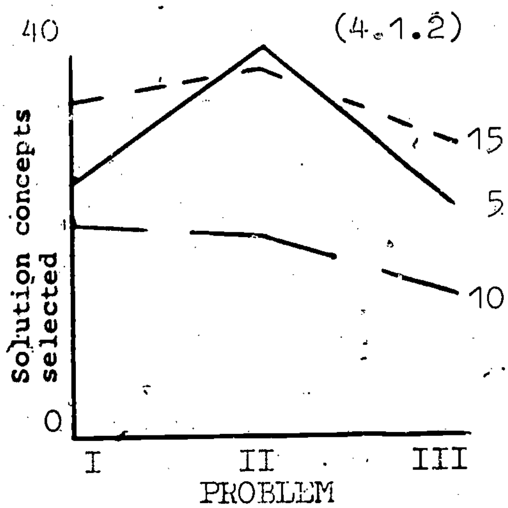
Interaction p = .01

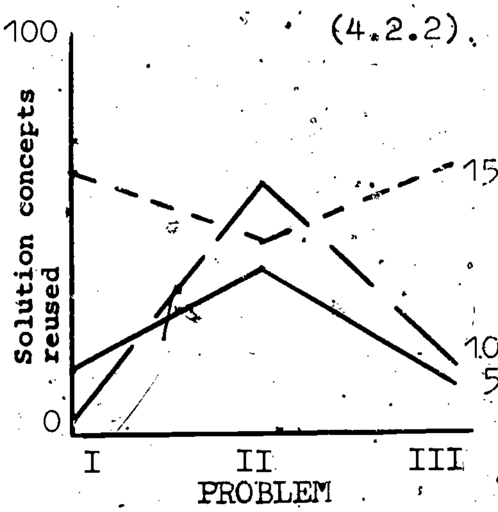


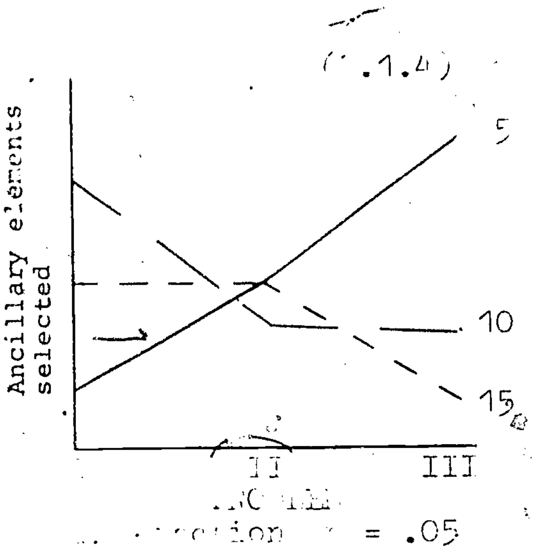
Interaction p = .10

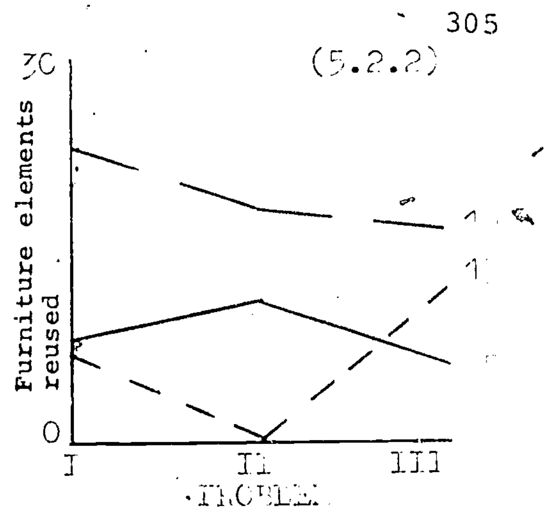


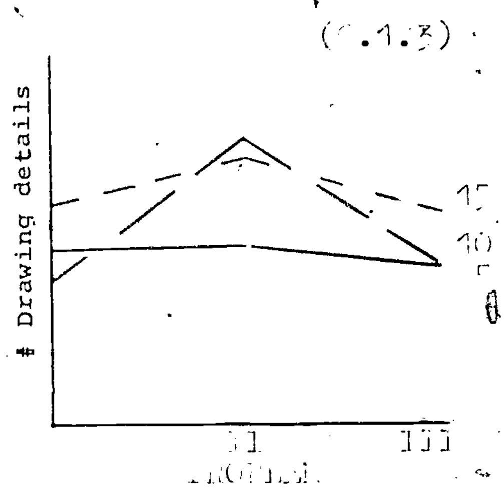


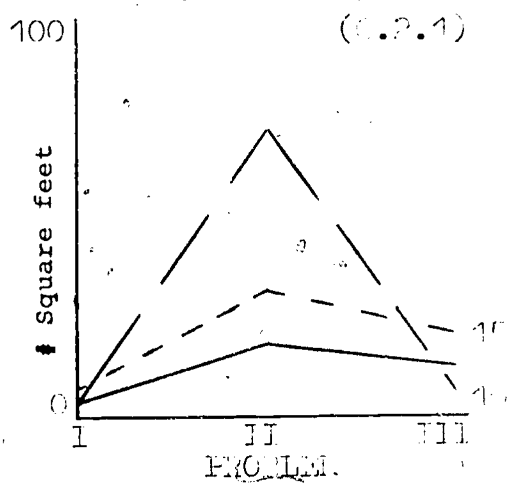


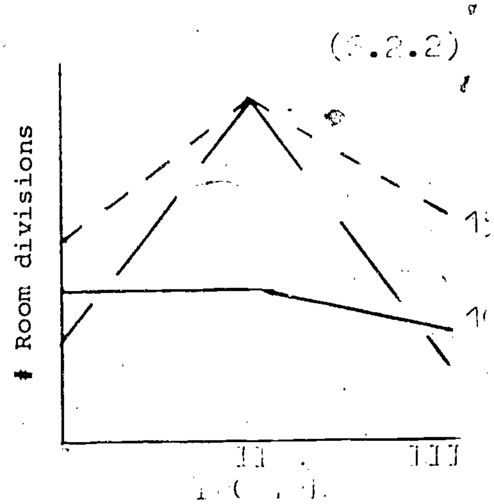


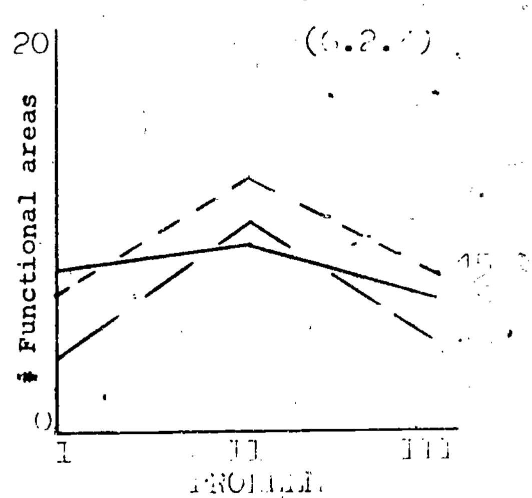

(5.1.4)
Ancillary elements selected
5
10
15
II
III
PROBLEM
= .05


(5.2.2)
30
Furniture elements reused
0
I
II
III
PROBLEM


(5.1.3)
Drawing details
15
10
II
III
PROBLEM


(5.2.1)
100
Square feet
0
I
II
III
PROBLEM


(5.2.2)
Room divisions
II
III


20
Functional areas
0
I
II
III
PROBLEM

APPENDIX J INFORMATION BANK BIBLIOGRAPHY

This lists the major references used in developing the information banks for this experiment, including specific sources which were described generally in Appendix C-1. The general areas of application of each reference are indicated, following the citation, by code letters: (A) = Design Principles and Techniques, (B) = Behavioral Criteria and Research, (C) = Human Factors Criteria and Standards, (D) = Educational Facilities Design, (E) = Office and Conference Room Design, (F) = Snack Bar Design, (G) = Architectural Design Handbooks, including aspects of human factors standards, educational, office, and eating facility design. (Note: articles from collections listed in the main bibliography are referenced only by editor, see main listing for details).

INFORMATION BANK BIBLIOGRAPHY

1. Alexander, D., "A City is not a Tree", Design, February, 1966, pp. 46-55. (A)

2. Alger, J. R. M., Hays, C. V., Creative Synthesis in Design, Englewood Cliffs, N. J., Prentice-Hall, 1964. (A)

3. Bennett, E.; Degan, J.; Spiegel, J., Human Factors in Technology, N. Y., McGraw-Hill, 1963. (C)

4. British Standards Institution, Anthropometric Recommendations for Dimensions of Non-Adjustable Office Chairs, Desks, and Tables, London, 1959. (C)

5. Branch, M. C., Planning: Aspects and Applications, N. Y., Wiley, 1966. (A,B)

6. Brookes, M. J., "American Views on Design Education", Design, December, 1966, pp. 52-53. (A, B)

7. Brookes, M. J., "A Maze of Contradictions", Progressive Architecture, November, 1969, pp. 130-131. (B)

8. Brower, S., "The Expressive Environment", Architectural Forum, April, 1966, pp. 38-39. (B)

9. Callender, J. H., Time-Saver Standards: A Handbook of Architectural Design, N. Y., McGraw-Hill, 1966. (G)

10. Carr, R., "Desk Dividers", Design, January, 1969, pp. 38-39. (E)

11. Chapanis, A., Research Techniques in Human Engineering, Baltimore, Johns Hopkins, 1959. (B, C)

12. Cuddon, R., "Office Furniture", Architectural Review, November, 1966, pp. 369-370. (E)

13. Daniels, E. G., "Changes in Food Service Technology - and How They Affect Design", Architectural Record, August, 1966, pp. 145-148. (F)

14. Dreyfus, H., The Measure of Man, N. Y., Whitney Library, 1960. (C)

15. Dreyfuss, H., "People Come in Assorted Sizes", Human Factors, August, 1966, pp. 273-277. (C)

16. Eder, W. E., "Definitions and Methodologies", in S. Gregory, 1966, pp. 19-31. (A)

17. Floyd, W. F.; Roberts, D. F., Anatomical, Physiological

and Anthropometric Principles in the Design of Office Chairs and Tables, London, British Standards Institution, 1958. (C)

18. Foxhall, W. B., "Design Elements of Food Services for Colleges and Universities", Architectural Record, April, 1962, pp. 184-188. (F)

19. Frame, S. J.; McLeod, J. W., Buildings and Facilities for the Mathematical Sciences, Washington, D. C., Conference Board of the Mathematical Sciences, 1963. (D)

20. Gregory, C. E., The Management of Intelligence: Scientific Problem-Solving and Creativity, N. Y., McGraw-Hill, 1967. (A, B)

21. Handler, A. B., "The Place of Social Science in Architecture", Architectural Science Review, December, 1964, pp. 124-135. (B)

22. Horowitz, H., "The Program's The Thing", AIA Journal, May, 1967, pp. 94-100. (A)

23. Hughes-Stanton, C., "Selling by Machine", Design, September, 1961, p. 81. (F)

24. Johnson, K. E., "The Office Environmental People Prefer", AIA Journal, February, 1970, pp. 56-58. (B, E)

25. Jones, J. C., "A Metnod of Systematic Design", in Jones and Thornley, 1963, pp. 53-73. (A)

26. Jones, J. C., "Design Methods Compared 2: Tactics", Design, September, 1966, pp. 46-52. (A)

27. Kelly, S., "Office Design", Industrial Design, February, 1966. (E)

28. Kiyoshi, I., "Psychological Phenomena and Building Design", Building Research, July-August, 1965, pp. 9-11. (B)

29. Knapp, M. A., "Planning for Dining and Serving Areas in Nursing Homes", Hospitals, November, 1966, pp. 140-142. (F)

30. McCormick, E. J., Human Factors Engineering, N. Y., McGraw-Hill, 1964. (C)

31. McVey, G. F., Environment for Learning, Madison, Wisconsin, Multimedia Instructional Laboratory, 1969. (B, C)

32. Manser, J., "Furniture for an Office Landscape", Design, March, 1969, pp. 46-63. (E)

33. Martin, D. J., The Interpretive Classroom, Instructional Research and Development Paper, No. 2, Marin County, California, Marin College, Office of Instructional Research and Development. (D)

34. Meade, D., "The Odd Ergonomic Inch and Why it Matters in the Office", Design, April 1966, pp. 38-44. (C)

35. Morgan, C. T.; Chapanis, A.; Cook, J. S.; Lund, M. W., Human Engineering Guide to Equipment Design, N. Y., McGraw-Hill, 1963. (C)

36. National Stationary and Office Equipment Association, How to Plan Your Office Layout: A Guide for Planning A Modern, Efficient Office, Washington, D. C., 1953. (E)

37. Nelson, G., Problems of Design, N. Y., Whitney Library of Design, 1965. (A, B)

38. Norberg-Schultz, C., Intentions In Architecture, Cambridge, Mass., MIT Press, 1966. (B)

39. Osborn, A. F., Applied Imagination, N. Y., Scribner, 1963. (A)

40. Papyannis, T.; Venezia, A., "The Future of Architecture", Arts and Architecture, November, 1965, pp. 18-22. (B)

41. Parr, A. E., "Environmental Design and Psychology", Landscape, Winter, 1964-65, pp. 15-18. (B)

42. Pye, D. W., The Nature of Design, N. Y., Reinhold, 1964. (A, B)

43. Ramsey, C. G.; Sleeper, H. R., Architectural Graphic Standards, 6th Edition, N. Y., Wiley, 1970. (G)

44. Rapoport, A.; Kantor, R. E., "Complexity and Ambiguity in Environmental Design", AIA Journal, July, 1967, pp. 210-221. (B)

45. Saphier, M., Office Planning and Design, N. Y., McGraw-Hill, 1968. (E)

46. Sommer, R., Personal Space, Englewood Cliffs, N. J., Prentice-Hall, 1969. (B)

47. Studer, R. G., "Some Aspects of the Man-Environment Interface", in Coates and Moffett, 1969, pp. 77-100. (B)

48. Studer, R. G.; Stea, D., "Architectural Programming, Environmental Design and Human Behavior", J. of Social Issues, 12, 4, 1966, pp. 127-136. (B)

49. Thornley, D. G., "Design Methods in Architectural Education", in Jones and Thornley, 1963, pp. 37-51. (A)

50. University of Wisconsin, Department of Planning and Contruction, "Building Program: Center for Research on Mental Retardation and Related Aspects of Human Development", Madison, University of Wisconsin, October, 1967. (B, D)

51. University of Wisconsin, Department of Planning and Construction, "Building Program: Animal Science Building", Madison, University of Wisconsin, April, 1968. (B, D)

52. Vermilya, H. P., "Vending Machines Work for Food Service", Architectural Record, May, 1963, pp. 194-196. (F)

53. Woodson, W. E.; Conover, D. W., Human Engineering Guide for Equipment Designers, 2nd Ed., Berkeley, U. of Calif. Press, 1964. (C)

54. Zevi, B., Architecture as Space, N. Y., Horizon Press, 1957. (B)

55. Zwicky, F.; Wilson, A. G., eds., New Methods in Thought and Procedure: Contributions to the Symposium on Methodologies, N. Y., Springer-Verlag, 1967. (A)

56. "Coming: The Automated Salesroom", Architectural Forum, December, 1968, pp. 122-123. (F)

57. "A Designer's Thoughts on Eating Out', Design, April, 1967, p. 20. (F)

58. "From Grid to Growth", Progressive Architecture, November, 1969, pp. 100-109. (E)

59. "Metric Office Furniture", Design, August, 1969, pp. 30-31.

60. "Motorway Service Area", Architectural Design, January, 1969, pp. 19-20. (F)

61. "Room for Self-Criticism", Progressive Architecture, November, 1969, pp. 122-123. (E)

62. "The Trend in Vending", Design, August, 1968, p. 10. (F)